GLASSHOUSE CROPS RESEARCH INSTITUTE

ANNUAL REPORT 1961

RUSTINGTON
LITTLEHAMPTON . SUSSEX

The abbreviated title of this Report as given in the World List of Scientific Periodicals is:—

Rep. Glasshouse Crops Res. Inst.
1961

Copies of this report may be obtained from the Institute's Librarian, price 10/– (post free)

PRINTED BY
MITCHELL & CO. (PRINTERS) LTD.
53 HIGH STREET
ARUNDEL, SUSSEX
1962

THE GLASSHOUSE CROPS RESEARCH INSTITUTE

The Glasshouse Crops Research Institute was established on 8 September 1953 as a company limited by guarantee, but without share capital, under the Companies Act of 1948. Its registered office is at Littlehampton, Sussex, where the main research station is being developed. The Institute succeeded the Experimental and Research Station at Cheshunt, which was in existence from 1915 to 1955, and also took over the work of the Mushroom Research Station at Yaxley, which functioned from 1946 to 1954.

In the Memorandum of Association the principal object for which the Institute has been established is stated as follows:

> "To promote scientific research bearing on the cultivation of glasshouse crops and mushrooms, and of bulbs, flowers and shrubs grown in the open, and on matters ancillary thereto".

The Institute is administered by a Governing Body consisting, at present, of fourteen members, including the Chairman, Sir William K. Slater, K.B.E. Six members are leading commercial growers who represent the section of horticultural industry served by the Institute, six are eminent scientists, and one was until his recent retirement a Senior Education and Advisory Officer of the Ministry of Agriculture, Fisheries and Food.

The Institute is financed almost entirely by grants from the United Kingdom Treasury. Since 1 April 1956 these have been administered by the Agricultural Research Council, which exercises general supervision over the Institute's staffing and research programme.

The Institute has a Subscription Scheme which enables growers and others to associate themselves with its work and to take a closer and more personal interest in the research that is being carried out. The minimum subscription rates are five guineas per annum for firms or companies, and two guineas per annum for growers working on their own account or for other individuals interested. A reduced rate applies to those overseas. Those subscribing receive a copy of the Annual Report and an invitation to attend the annual Open Day or any special demonstrations arranged for growers. Other privileges, for example, the issue of trial quantities of improved seed, may be offered from time to time. Further particulars of the Scheme may be obtained from the Secretary of the Institute.

The Institute's research station at Littlehampton is situated in the heart of the important West Sussex glasshouse area. This is also an important area for mushroom production. The station is thus well placed for its work and for maintaining contact with the industry the Institute has been set up to serve. The research station occupies about 100 acres of land, on soil of the brick earth type. The greater part of this land is required as a reserve for future work with outdoor crops, for the supply of loam, and for resoiling the glasshouses when experimental work requires it.

Development of the research station is still proceeding but has already reached an advanced stage. In addition to an administration building, which also houses the library, there is a well-equipped block of laboratories with an annex for special services. There are also 1·77 acres of permanent glass for large scale experiments and trials, as well as research glasshouses for work in the fields of plant physiology, plant pathology, chemistry and crop protection. A special unit, including three growing houses, for work on mushrooms completes the research facilities, which are supported by a wide range of ancillary buildings, such as boiler houses, potting sheds, stores, etc. Other research facilities are being planned.

The scientific and experimental staff of the Institute at present (31 December 1961) numbers 35, most of whom are honours graduates.

Digitized by the Internet Archive
in 2025

https://archive.org/details/annual-report-glasshouse-crops-research-institute_1961

GLASSHOUSE CROPS RESEARCH INSTITUTE

GOVERNING BODY

Chairman

Sir WILLIAM K. SLATER, K.B.E., D.Sc., F.R.I.C., F.R.S.

Vice-Chairman

L. C. MADSEN, ESQ.

Professor N. A. BURGES, M.Sc., PH.D.

D. G. FRAMPTON, ESQ. (*from 10.1.61*)

Professor F. G. GREGORY, D.Sc., F.R.S. (*until 25.10.61*)

C. E. HUDSON, ESQ., C.B.E., N.D.H., V.M.H.

Professor J. P. HUDSON, M.B.E., G.M., M.Sc., PH.D., N.D.H.

Lt.-Col. L. R. LEACH, M.C., J.P.

J. LEEMING, ESQ.

N. S. LIVERMAN, ESQ., J.P.

Professor HELEN K. PORTER, D.Sc., D.I.C., F.R.S. (*from 26.10.61*)

Professor O. W. RICHARDS, M.A., D.Sc., F.R.S. (*from 26.10.61*)

THOS. ROCHFORD, ESQ.

Sir GERARD THORNTON, B.A., D.Sc. F.R.S. (*until 25.10.61*)

Professor R. L. WAIN, D.Sc., PH.D., F.R.I.C., F.R.S.

Professor W. T. WILLIAMS, A.R.C.S., D.I.C., D.Sc., PH.D., F.L.S.

Architects

Messrs. COWPER, POOLE & PARTNERS,
39 Gordon Square, London, W.C.1.

Auditors

Messrs. GEORGE COBLEY & CO.,
52 Lincolns Inn Fields, London, W.C.2.

Bankers

MIDLAND BANK LTD.

Solicitors

Messrs. MACDONALD STACEY MEREDITH HARDY & HUTCHISON,
7 & 8 King's Bench Walk, Temple, London, E.C.4.

GLASSHOUSE CROPS RESEARCH INSTITUTE

Director

F. W. TOOVEY, O.B.E., B.SC.(Lond.), A.R.C.S., A.I.C.T.A., M.I.BIOL.

SCIENTIFIC STAFF

Plant Breeding

L. A. DARBY, B.SC.(Wales)
A. C. HASTIE, B.SC.(Glasgow) (*until 17.9.61*)
J. PELHAM, B. A.(Oxon.) (*from 28.8.61*)
J. W. M. SMITH

Assistants

Miss P. R. AINSLEY, Miss H. W. HAIGH (*from 1.5.61*)

Plant Physiology

E. R. LEONARD, D.SC.(Lond.), A.R.C.S., M.I.BIOL., M.INST.R.
H. R. B. HACK, B.A.(Cantab.), M.I.BIOL.

Assistants

R. BROWN, Z. J. KULWIEC (*until 30.4.61*), Mrs. C. JONES (*née* Jones, *until 30.11.61*), Miss J. MALEY (*from 1.7.61*), M. BUTTON (*from 20.11.61*)

Chemistry

G. W. WINSOR, B.SC.(Bristol), PH.D.(Lond.), D.I.C., A.R.I.C.
J. N. DAVIES, B.SC., PH.D.(Lond.)
J. H. L. MESSING, B.SC.(Wales)
D. M. MASSEY, B.SC.(Bristol), M.I.BIOL.
M. I. E. LONG
G. E. HOBSON, B.SC.(Nottingham), M.SC.(Lond.)

Assistants

P. ADAMS, Miss M. COLEMAN (*until 5.5.61*), Miss B. MARSHALL, K. V. AYLING (*until 22.5.61*), Miss R. BOWERMAN, Miss L. NASH (*until 5.8.61*), Miss E. KENDALL (*from 23.5.61*), Miss L. BANFIELD (*from 15.5.61*), Miss D. BOYS (*from 28.8.61*)

Statistics

D. COOKE, M.A., DIP.STAT.(Oxon.)
J. H. GISBORNE, A.I.C.T.A. (*from 1.4.61*)

Assistants

Miss E. J. WINGATE (*until 3.2.61*), Mrs. B. HOWARD (*from 6.2.61*)

Plant Pathology Division

L. BROADBENT, D.Sc.(Lond.), PH.D., M.I.BIOL.

Entomology

N. W. HUSSEY, B.Sc.(Wales), PH.D.(Edin.)
W. J. PARR, M.I.BIOL.
I. J. WYATT, B.Sc.(Lond.), DIP.AGRIC.SCI.(Cantab.), DIP.TROP.SCI.(Trinidad)
Miss B. GURNEY

Assistant

R. I. MITCHELL

Nematology

J. J. HESLING, B.Sc.(Lond.), A.R.C.S.

Assistant

Miss R. SUTTERS (*from 27.2.61*)

Mycology & Bacteriology

P. H. WILLIAMS, B.Sc.(Lond.), M.I.BIOL. (*until 30.9.61*),
F. T. LAST, B.Sc.(Lond.), PH.D.(Lond.), A.R.C.S., D.I.C., M.I.BIOL. (*from 1.12.61*)
Miss M. H. EBBEN, M.A.(Cantab.), M.I.BIOL.
Miss D. G. GANDY, M.Sc.(Lond.)

Assistants

Mrs. P. ROBBINS (*née* Shoesmith, *until 12.8.61*), Miss J. KERNER,
Miss G. BALCHIN (*from 14.8.61*)

Virology

M. HOLLINGS, B.Sc.(Nottingham), M.I.BIOL.
R. HOWLES, B.A., PH.D.(Cantab.) (*until 13.4.61*)
Miss O. M. STONE, M.A., PH.D.(Cantab.), M.I.BIOL.
Miss M. E. NORRISH

Assistants

R. PAWLEY, P. WEATHERDON

Crop Protection

W. H. READ, M.Sc.(Birmingham), F.R.I.C.
R. J. SMITH, B.Sc., PH.D.(Lond.), A.R.I.C.
J. T. HUGHES, B.Sc.(Lond.), A.R.I.C.
Mrs. V. A. COOKE, B.Sc.(Hull)
Miss P. M. SMITH, B.Sc.(Lond.)

Assistants

Miss J. MARTIN, Miss B. HOTSTON, Miss B. FINCH

Horticulture

G. F. SHEARD, M.Sc.(Leeds)
A. J. COOPER, B.Sc.(Lond.), PH.D.(Reading)
P. B. FLEGG, B.Sc.(Reading), A.R.I.C., M.I.BIOL.
A. C. BUNT, N.D.H.(Hons.)
Z. J. KULWIEC (*from 1.5.61*)

Assistants

Miss I. I. WARMAN, Miss N. PESCOTT, Mrs. P. CORNISH

Technical Services & Maintenance

J. E. MORTON, A.R.P.S., F.R.M.S., M.I.BIOL.

Instrument Technician

R. E. RANDALL

Assistant

Miss G. MARSH

Maintenance Staff

W. M. TOMLINSON, R. FROST, R. MINGAY, G. CARRE, B. ROCKALL (*until 3.2.61*)
A. W. SMART (from *13. 3.61*), D. P. HART (*from 5.4.61*),
F. C. FORSTER (*from 11.12.61*)

Scientific Liaison Officer

G. F. SHEARD, M.SC.
(*also Head of the Horticulture Department*)

ADMINISTRATION

Secretary

J. BISHOP, A.C.I.S.

Accounts Officer

D. M. HART, A.C.I.S.

Director's Secretary

Mrs. E. J. BESWICK

Clerical Staff

Miss M. M. K. BALDWIN (*until 10.11.61*), Miss R. M. JONES, Miss J. MCCARTHY,
Miss M. M. DUNSTER, Miss P. D. SMITH (*6.2.61 to 19.5.61*),
Miss J. M. SAUNDERS (*from 29.5.61*), Miss M. F. PITT (*from 27.11.61*)

Librarian

Miss G. DUNSTER, B.A.(Lond.) (*until 31.3.61*)
Miss M. E. M. PRICE, DIP.LIB.(Toronto) (*from 1.5.61*)

NURSERY

Nursery Manager and Demonstrator

J. M. EVANS, N.D.H.

Foreman

L. TOMS

Nursery workers with more than five years' service at 31.12.61

F. BLAKE (*33 years*), P. DAWES, Miss R. MILLS, S. BARNETT,
N. DALGARNO, D. POWELL

TABLE OF CONTENTS

			Page
I.	INTRODUCTION		
	Director's Administrative Report and Review of Research		11
	Nursery Manager's Report	*J. M. Evans*	40
II.	RESEARCH SUMMARY : DEPARTMENTAL & SECTIONAL REPORTS		
	1. Plant Breeding	*L. A. Darby*	43
	2. Plant Physiology	*E. R. Leonard*	47
	3. Chemistry	*G. W. Winsor*	49
	4. Statistics	*D. Cooke*	61
	5. Entomology	*N. W. Hussey*	62
	6. Nematology	*J. J. Hesling*	66
	7. Mycology & Bacteriology	*F. T. Last*	68
	8. Virology	*M. Hollings*	70
	9. Crop Protection	*W. H. Read*	78
	10. Horticulture	*G. F. Sheard*	87
III.	SPECIAL RESEARCH REPORTS		
	Entomology		
	1. Response of the cucumber plant to different levels of artificial leaf damage in an attempt to simulate the effects of Red Spider Mite	*W. J. Parr and N. W. Hussey*	95
	Virology		
	2. The attenuation of Carnation Mottle Virus in plants	*M. Hollings and Olwen M. Stone*	100
	3. Die-back of mushrooms: a disease associated with a virus	*Doreen G. Gandy and M. Hollings*	103
	Horticulture		
	4. The relations between daylength and the growth of the fruit of the tomato	*A. J. Cooper*	109
	Horticulture & Statistics		
	5. The effect of rate of spawning on the cropping of the cultivated mushroom	*D. Cooke and P. B. Flegg*	118
IV.	APPENDIX		
	Publications 1961		123
	Meteorological Records 1961		125
	PLAN OF INSTITUTE'S LAYOUT		126

I. INTRODUCTION

The year under review was largely a period of consolidation, but there was a modest increase in research staff, and a new phase of capital development, which included one large project, was initiated.

Governing Body

The passage of time has brought further changes in the Governing Body and we were very sorry to have to take leave of Professor F. G. Gregory and Sir Gerard Thornton, both of whom retired at the end of their current period of office on 25 October 1961. Both had served on the Governing Body since the inception of the Institute in 1953, and no members could have taken a greater interest in our affairs or have done more to advance the work of the Institute. Professor Gregory's association with glasshouse research went right back to the early days of the Cheshunt station as he was doing physiological work there as long ago as 1916. Although his health had not been good for some time we were all distressed to learn of his death on 27 November, as it meant the loss of a great friend of the Institute. At his funeral Professor W. T. Williams, one of his colleagues on the Governing Body, paid a tribute to one who in the words of an obituary in "The Times" had "an almost legendary international reputation as a figure of great significance in the development of modern plant physiology."

To fill the vacancies left by the retirements mentioned, Professor Helen Porter, F.R.S., and Professor O. W. Richards, F.R.S., both of the Imperial College, have been appointed, and we offer them a very warm welcome. Professor Richards is no stranger to the Institute as he came with the A.R.C. Visiting Group in 1959.

Congratulations go to Professor R. L. Wain, Chairman of the Staff and Research Committee, who was awarded the Royal Agricultural Society of England's Research Medal for 1961. Professor W. T. Williams was appointed a member of the Agricultural Research Council, while Colonel Leach was appointed to the Market Managements Committee of the Covent Garden Market Authority. Sir Gerard Thornton was elected President of the Institute of Biology for 1961.

The Governing Body met on four occasions during the year. The 20th Meeting on 11 January 1961 was preceded by the Annual General Meeting when the Chairman's Report and Accounts and Balance Sheet for the year ended 30 September 1960 were approved and adopted.

It was only necessary to convene one meeting of the General Purposes Committee, on 27 July 1961, to consider the tenders for the plant pathology research glasshouse and laboratory unit. The Staff and Research Committee held two main meetings, and a quorum of the Committee was convened on two other occasions to interview candidates for appointment to the scientific staff. Special committees were convened on 24 March and 21 December to fill vacancies for the posts of Librarian and Secretary respectively.

Staff and students

Mr. P. H. Williams, Head of the Mycology Department, retired on 30 September. His service at the Institute and at the former Experimental and Research Station at Cheshunt extended over a total period of 38 years, a record of which he can be justly proud. Our very best wishes go with him in his retirement. A presentation was made to him on behalf of the staff on his last day at the Institute.

Dr. F. T. Last, B.Sc., Ph.D., A.R.C.S., D.I.C., M.I.Biol., of the Rothamsted Experimental Station, was appointed to succeed Mr. Williams, and formally assumed duty on 1 December.

Mr. A. C. Hastie, Plant Breeder, resigned on 30 September, and was replaced by Mr. J. Pelham, B.A., whose appointment dated from 28 August.

The scientific staff was further expanded by two new appointments in the Assistant Experimental Officer grade. Mr. J. H. Gisborne joined the Statistics Section on 1 April, and Mr. Z. J. Kulwiec was appointed to the Horticulture Department on 1 May on promotion from the grade of Scientific Assistant, a post he held in the Plant Physiology Department.

As usual there were several changes in the staff of Scientific Assistants which are shown in the staff list published at the beginning of this report. Two new posts in this grade were filled, and a Laboratory Attendant to assist the Instrument Technician was also appointed.

Miss G. Dunster, who had served at Cheshunt and at the Institute over a total period of twenty years, for much of the time as Secretary but latterly as Assistant Secretary and Librarian, resigned for domestic reasons at the end of March. She, too, was the recipient of a presentation from the staff, some of whom arranged a theatre party for her just before she left. Miss Dunster's post as Librarian was filled by Miss M. E. M. Price, Dip.Lib.(Toronto), who had previously occupied a similar position at the Imperial College of Tropical Agriculture in Trinidad. She assumed duty on 1 May.

We again engaged a number of students (about a dozen altogether) for short periods during the summer to help out with the recording in the glasshouses and for other duties which always fall particularly heavily at that time of year.

Another Brunel College student, Miss J. A. Graves, who was taking a sandwich course for the Diploma in Technology in Applied Biology, was with us from April to September for her "industrial training", spending part of her time on the nursery and then with the Entomology Department.

We again have a student (M. Withnall) doing his year's practical pre-graduate training at the Institute, this time before proceeding to a degree course at Wye College.

Under the scheme promoted by the Agricultural Apprenticeship Council we are now engaging nursery apprentices as a matter of regular policy, at the rate of about one a year. By the end of the year three nursery workers, who had been at the Institute for various lengths of time, had signed a Deed of Apprenticeship.

Capital developments

Early in the year we received Treasury authority to invite tenders for the research glasshouse and laboratory unit for the Plant Pathology Division on the basis of the design plans for the scheme prepared by the Architects. After detailed drawings and specifications had been prepared tenders were invited from seven firms, but the situation in the building industry did not encourage keen competition and three of the firms withdrew, while the tenders received from the others were embarrassingly higher than we were expecting. We were nevertheless authorised to accept the lowest tender, and a capital grant was in due course received from the A.R.C. to cover the project. The contract provided for work to begin early in September, but there was some delay in starting because bricks ordered many months previously did not arrive in time. By the end of the year, however, the foundations had been laid, and we were all relieved that

this immense project, which had received so much thought and planning, and which was so anxiously awaited for the full development of our work in plant pathology, was at last under way. It will be recalled that the scheme will provide facilities for virus, entomological and nematological work in one unit comprising a compartmented and screened glasshouse (in two sections), with attached laboratories, potting shed and constant temperature rooms.

For reasons which seemed largely beyond our control further delays occurred in installing the new heating system for the trial glasshouses, but it was partly in operation by the end of the year. The new boilers were started up in October, and after some initial troubles, the cause of which took a little time to track down, they have been functioning satisfactorily. Work has proceeded slowly on the distribution mains and re-piping of the houses, the latter having to be done with the minimum of dislocation to the experimental cropping programme. A steam link has been installed between the new boiler house and the one serving the research glasshouses; this will ensure the greatest flexibility and economy in operating the heat-producing units on the station.

The new boilers have a heat capacity of 3·35 and 6·69 million B.t.u. per hour respectively, and with the one serving the research glasshouses, which has a capacity of 2·25 million B.t.u. per hour, we shall have sufficient heat capacity for all foreseeable developments. The new boilers produce steam, and heat exchange is arranged through calorifiers of a new type into small-bore pipes through which water is circulated by means of pumps.

A very welcome capital development has been the extension of the area of trial glasshouses available for plant breeding which has been made possible by a generous grant provided by the States of Guernsey. This was the culmination of lengthy negotiations in the course of which the Guernsey authorities had expressed their keen interest and confidence in the work being done at the Institute on the production of new varieties of tomatoes and their anxiety to see it extended so that attention could be given to varieties satisfying a wider range of conditions and requirements. The Guernsey decision to support the Institute's plant breeding work was part of their more extensive proposals for developing the island's advisory service.

The "Guernsey" glasshouses are four in number and are of a standard commercial type. They are of alloy construction, 30ft. wide, and each 57ft. long. One of the houses is to be divided into six compartments running off a central corridor. The four houses had been erected and glazed by the end of the year, but the heating system remained to be installed.

Another addition to the station's glass was a new propagating house which was also erected in the latter part of the year. The house is 100ft. long by 20ft. wide, and again is of alloy construction, with the minimum of light obstruction. It provides excellent conditions for propagation and is a very welcome addition to our facilities during the winter months when light is a critical factor.

A number of minor capital projects were approved, but the only one on which a start had been made by the end of the year was a Dutch barn erected next to the main potting shed. This is for the storage of loam and equipment.

Subscription Scheme

There has been an encouraging increase in support for the Subscription Scheme. This scheme enables growers and others to keep in close touch with the work of the Institute, and in this way they can help to guide the Institute in serving the industry. Subscribers receive copies of the Annual Report, and are entitled to attend open days. The latter provide valuable oppor-

tunities for the exchange of ideas and views with research workers on the staff. Other privileges for Subscribers are shortly to be reviewed, but in the meantime it may be mentioned that a special issue of seed of tomato varieties bred at the Institute was made to those requiring it for trial on their holdings. Details are given in the section summarizing the research programme. The present policy is to let our Subscribers have the first opportunity of testing any new planting material we produce, after it has undergone country-wide trials by a small panel of growers in each region selected by the N.A.A.S.

By the end of the year the numbers participating in the Subscription Scheme were as follows:

Companies or firms	89
Individuals	123
Overseas subscribers	8
	220

We again express our indebtedness to this small band of growers and others who show their interest in our work in this way.

A.R.C. Visiting Group

In the report of the Visiting Group which came in 1959 to review the work of the Institute and to consider proposals for the future it was suggested that the Group should be called together for another visit to the Institute in about two years' time when the comparatively new Plant Pathology Division and the newly created Horticulture Department would have had time to settle down. We were accordingly very glad to have the opportunity of receiving the Group again for a one day visit on 16 November 1961, and put before them proposals not only in connection with the Departments mentioned but also some relating to developments since the Group's earlier visit. Once again we must thank the Group for their careful attention to our affairs and for the helpful discussions we were able to have with them. Their supplementary report was not received until after the end of the year.

Library

As recorded above, Miss Price joined the staff of the Institute on 1 May to take charge of the library. As a qualified librarian it was natural that she should want to bring her training and experience to bear on the organisation of the library, and the collection has been completely re-arranged, shelving numbered and all periodicals and series publications located by shelf number on a Wall Index. Text books filed in the library have been checked for cataloguing and U.D.C. classification, the various existing catalogues combined and a classified subject catalogue made. Cataloguing of text books held departmentally has been started, but much work still remains to be done on these scattered collections and on the material, other than text books, in the library itself.

During the year ten new periodical subscriptions were placed and at the end of this period 223 periodical titles were being received—105 of these by subscription, the remainder free or in exchange for our Annual Report.

To enable us to make good deficiencies in the Library, particularly of text books, the Governing Body generously allowed us to draw on a special grant of £1,000 made available from the General Purposes Fund. During the year some 110 text books, micro-cards of early volumes of three periodicals, a much-needed new typewriter, a ten-drawer catalogue cabinet and other equipment were obtained from this grant.

The library is served by a Library Committee consisting of the Director, the Librarian, and three senior members of the staff with a special interest in library work. The Committee met four times during the year.

Miscellaneous

Staff social activities

The Staff Association continues to be active and arranged the usual party at Christmas, which was voted a great success. The fireworks party for the children was also held at the traditional time and provided much enjoyment for those taking part. The Horticultural Society again held a show at the end of August which was well supported.

Liaison

The Director accepted an invitation to serve on the Advisory Committee of the Rosewarne Experimental Horticulture Station, an indication of the Institute's increasing concern with the problems of the bulb industry. We are now represented on the Advisory Committees of most of the N.A.A.S. Experimental Horticulture Stations, the work of which forms such an important link between the Institute's work and its application to the grower. Several members of the staff also serve on the Working Parties of the Agricultural Improvement Council which are responsible for many of the experiments at those stations in which the Institute has an interest. In this way we are able to keep in very close touch with the work of these stations, and it is a pleasure to take this opportunity of recording once again our appreciation of the help and collaboration we have had from the Directors.

Liaison with the county officers of the National Agricultural Advisory Service remains as close as ever, and provides another invaluable link with the industry. We must depend very largely on the N.A.A.S. for making our work known to the grower, although as will be evident later we are using the direct approach more and more through the services of our Liaison Officer, Mr. Sheard, and other members of the staff who give much of their time speaking to growers up and down the country.

The distribution of seed of new tomato varieties bred at the Institute has brought us into contact with the National Institute of Agricultural Botany at Cambridge, and we are very pleased to acknowledge the ready co-operation we have had from that Institute in dealing with our affairs. The Director has now been invited to serve on the N.I.A.B. Root and Vegetable Seeds Committee.

Mr. Sheard has joined the Editorial Board of "The Grower", and has also accepted an invitation to serve on the Electrical Research Association's Research Committee 5J: Applications of Electricity to Horticulture.

Open Day

The Open Day was held a little later this year—on 25 May—in order not to clash with the Chelsea Show. The weather was again kind, and from all accounts the event appears to have been regarded as more successful than ever. On this occasion we made a special effort to encourage growers within reasonably easy reach of the Institute to attend, and we are greatly indebted to the N.A.A.S. County Horticultural Officer for assisting us to contact them. Growers on the old Cheshunt membership list were also circularised. It was estimated that about 600 people attended during the day, but the number of Subscribers and guests who sat down to lunch was about the same as in previous years (168).

A special pre-view for the press was held on 12 May, ten journals and papers being represented.

Exhibitions and Shows

The Institute exhibited, for the first time since 1956, at the Chelsea Show, 16–19 May, and Mr. Darby, with the assistance of the Technical Services Unit, staged a display illustrating the breeding of new tomato varieties. The exhibit was outstandingly good, and all concerned in its preparation are to be heartily congratulated.

At the Sussex County Show held at Haywards Heath, 13–15 June, Dr. Cooper, again with the assistance of the Technical Services Unit, put up a demonstration of the effect of environment on the growth of the tomato and colour ripening disorders of the fruit. This was also first class, and although it could not qualify for an award in the commercial classes the judges gave it special mention in the following terms:

> "The judges would like to convey especially their praise and appreciation for this splendid exhibit, with its great educational value to the general public. While such an exhibit is non-competitive in its nature we feel both the staging and lay-out deserve great credit."

Conferences

Mr. G. E. Hobson, of the Chemistry Department, attended the Fifth International Congress of Biochemistry in Moscow, 10–16 August, and read a paper entitled "Enzymes associated with the abnormal ripening of tomato fruit."

Mr. J. J. Hesling took part in the VIth International Symposium of Plant Nematology in Ghent, 24–28 July.

These and other conferences in which members of the staff participated were as follows:

Date	*Place*	*Subject or Title of Conference*	*Staff attending*
January 2–4	Oaklands	Eastern Region Growers' Conference	G. F. Sheard M. Hollings Dr. O. M. Stone
January 26	Babbacombe	S.W. Region Horticultural Advisory Officers' Conference	Dr. G. W. Winsor
February 1	Hoddesdon	Conference on Red Spider Mite control	Dr. N. W. Hussey W. H. Read Dr. O. M. Stone

February 21–22	Keswick	N.A.A.S. Inter-Regional Horticultural Staff Conference	P. B. Flegg A. C. Bunt
February 22	Cheltenham	N.A.A.S. Glasshouse Conference	G. F. Sheard
February 28	London	Association of British Manufacturers of Agricultural Chemicals, Symposium on insecticides and fungicides in the soil	W. H. Read Dr. L. Broadbent
March 15	London	Open Conference of Advisory Plant Pathologists	D. Cooke
March 20–21	London	Symposium on fungicides in agriculture and horticulture held by Pesticides Group of Society of Chemical Industry	W. H. Read Miss P. M. Smith
March 22–24	Wellesbourne	A.R.C. Conference of Research Workers on Insecticides, Fungicides and Herbicides	W. H. Read
March 25	Wisbech	Conference on loamless composts	A. C. Bunt
April 5–7	London	Symposium on "Water Relations of Plants" held by the British Ecological Society	H. R. B. Hack
May 3	Sutton Bonington	East Midlands Horticultural Conference	M. Hollings
July 24–28	Ghent	VIth International Symposium of Plant Nematology	J. J. Hesling
August 10–16	Moscow	Fifth International Congress of Biochemistry	G. E. Hobson
September 19–20	Kent & Sussex	N.A.A.S. Entomologists' Open Conference	Dr. N. W. Hussey
September 21–22	London	Symposium on Insect Polymorphism	Dr. N. W. Hussey I. J. Wyatt
September 25	London	N.A.A.S. conference on "Temperatures for tomato growth"	G. F. Sheard Dr. A. J. Cooper
September 27	Cambridge	A.R.C. Conference of Plant Virus Workers	Dr. L. Broadbent M. Hollings Dr. O. M. Stone
October 2	London	Heating, Ventilating and Air Conditioning Exhibition and Conference	G. F. Sheard
October 12	Rothamsted	Soil Sterilants Conference	W. H. Read
October 17–18	Harrogate	N.A.A.S. Autumn Technical Conference	G. F. Sheard
October 19	Stockton	N.A.A.S. Conference	G. F. Sheard
November 2	London	Royal Society Virus Symposium	Dr. L. Broadbent
November 6–9	Brighton	British Insecticide and Fungicide Conference — Association of British Manufacturers of Agricultural Chemicals	F. W. Toovey W. H. Read Dr. L. Broadbent Dr. N. W. Hussey J. J. Hesling
November 17	Sunningdale	S.E. Region N.A.A.S. Horticultural Officers' Refresher Course	G. F. Sheard Dr. N. W. Hussey P. B. Flegg J. J. Hesling
November 25	East Grinstead	Area meeting of Mushroom Growers' Association	Dr. N. W. Hussey

Staff Colloquia

Purely domestic conferences, or Staff Colloquia, are held regularly during the autumn and winter months to enable members of the scientific staff to give an account of their work to

their colleagues, who then have the opportunity of discussing the subject generally. This does much to bring the research workers together and ensure that our efforts are co-ordinated.

The following colloquia were held during the year:

Date	*Subject*	*Speaker*
January 9	Investigations on tomato fruit composition; reference to question of flavour	Dr. G. W. Winsor Dr. J. N. Davies G. E. Hobson
February 6	Red Spider Mite investigations with special reference to problem of resistance	W. H. Read Dr. N. W. Hussey
March 13	Mushroom "Watery Stipe" disease	Miss D. G. Gandy
April 10	Planning experiments	D. Cooke
October 9	Tomato mosaic	Dr. L. Broadbent
November 13	Manganese toxicity	Dr. J. N. Davies J. H. L. Messing
December 11	Cucumber mildew	Dr. Olwen M. Stone W. H. Read

In addition to the above, Mr. Sheard gave a talk to the staff, on 8 May, on his visit to Holland.

Talks, lectures, papers by staff

Members of the staff again gave very many talks and lectures bearing on the work of the Institute. The full list, which includes papers delivered at some of the conferences mentioned above, is as follows:

January 1	Dr. G. W. Winsor	Participation in New Year programme on glasshouse horticulture in the "Farm in the South" series (Southern Television)
January 3	G. F. Sheard	"The application of research to, and experiments with carnations" (at the Eastern Region Growers' Conference at Oaklands)
January 26	Dr. G. W. Winsor	"Nutrition of glasshouse crops, with special reference to tomatoes, carnations and lettuce" (at the South West Region Horticultural Advisory Officers' Conference at Babbacombe)
February 8	M. Hollings	"Chrysanthemum and carnation viruses" (at the N.A.A.S. & N.F.U. Glasshouse Section meeting at Reading)
February 10	M. Hollings	"Some viruses of celery" (to the Association of Applied Biologists in London)
February 18	M. Hollings	"Some aspects of practical control of virus diseases" (at the Kent Horticultural Institute, Swanley)
February 21	P. B. Flegg A. C. Bunt	"Recent mushroom research" "Loamless composts" (at the N.A.A.S. Inter-Regional Horticultural Staff Conference at Keswick)
February 22	G. F. Sheard	"Work in progress at Littlehampton with special reference to tomatoes and cucumbers" (at the N.A.A.S. Glasshouse Conference, Cheltenham)
February 23	G. F. Sheard	"Work on loamless composts" (to the Hampton & Staines Horticultural Discussion Society)

February 23	A. C. Bunt	"Loamless composts and plant containers" (to the Stockton & Darlington Horticultural Discussion Group)
February 24	Dr. L. Broadbent	"Virus diseases of garden plants" (to the Worthing and West Sussex Horticultural Society)
February 24	Dr. G. W. Winsor	"Nutrition of glasshouse crops" (to the Surrey Horticultural Progress Club at Guildford)
March 1	Dr. L. Broadbent	"Control of virus diseases in potatoes and brassica crops" (at an open meeting in Bedford)
March 13	W. H. Read	"New pesticides" (to the Nazeing Growers' Discussion Group)
March 15	D. Cooke	"Experiments on glasshouse crops and vegetables" (at the Open Conference of Advisory Plant Pathologists in London)
March 20	W. H. Read	"Current practice and recent advances in control of fungus diseases in glasshouses" (at the Society of Chemical Industry Fungicide Symposium)
April 5	Dr. L. Broadbent	"Virus diseases of garden plants" (to the Lancing Horticultural Society)
April 15	G. F. Sheard A. C. Bunt	"Work of the G.C.R.I." "Loamless composts" (at the Weekend Course in Commerical Horticulture, organised by the N.A.A.S. and L.E.A., at Merrist Wood, Guildford)
April 17	F. W. Toovey	"The Glasshouse Crops Research Institute" (to the Bognor Regis Rotary Club)
May 3	M. Hollings	"Virus diseases of ornamentals" (at the East Midlands Horticultural Conference, Sutton Bonington)
May 29	G. F. Sheard	"G.C.R.I. compact-habit varieties" (at a N.A.A.S. discussion at Horam, Sussex)
June 7	F. W. Toovey	"The Glasshouse Crops Research Institute" (to the Companions' Club in Littlehampton)
June 18	Dr. G. W. Winsor	"Tomato fruit quality" (a talk on the B.B.C. Scottish Home Service)
August 2	Dr. N. W. Hussey	"The Glasshouse Crops Research Institute" (to the Swanage and Purbeck Rotary Club)
August 11	G. E. Hobson	"Enzymes associated with the abnormal ripening of tomato fruit" (at the Fifth International Congress of Biochemistry in Moscow)
September 11	J. M. Evans	"Some of the work of the Institute" (to the British Legion in Rustington)
September 19	F. W. Toovey	"The Glasshouse Crops Research Institute" (to the Bognor Round Table)
September 27	M. Hollings Dr. O. M. Stone	"The purification and use of formolised antigen to produce an antiserum to celery yellow vein virus" (at the A.R.C. Conference of Plant Virus Workers at Cambridge)
October 12	G. F. Sheard	"Impressions of the Dutch glasshouse industry" (to the N.W. Sussex Growers' Mutual Aid Group)
October 13	Dr. N. W. Hussey	"Control of Red Spider Mite on cucumbers" (to the Association of Applied Biologists in London)
October 17	G. F. Sheard	"A visit to Holland in 1961" and "Developments at G.C.R.I." (at the N.A.A.S. Autumn Conference at Harrogate)

October 19	G. F. Sheard	"Glasshouse cropping in England and Holland" (at the N.A.A.S. Conference at Stockton)
November 2	Dr. L. Broadbent	"Epidemiological factors of plant virus diseases" (at the Royal Society's Virus Symposium)
November 3	G. F. Sheard	"Recent developments in tomato growing" (at a N.A.A.S. growers' meeting in Cambridge)
November 3	Dr. G. W. Winsor	"Tomato fruit quality" (lecture organized by the Guernsey Education Authority)
November 7	Dr. L. Broadbent W. H. Read	"Systemic insecticides and virus control in potatoes" "Some recent investigations with chemical soil sterilants" (at the ABMAC British Insecticides and Fungicides Conference at Brighton)
November 7	G. F. Sheard	"The changing scene" (to the Somerset Glasshouse Growers' Club at Wells)
November 8	G. F. Sheard	"The work of the G.C.R.I." (to the South West Horticultural Discussion Group at Camborne)
November 9	L. A. Darby	"Tomato varieties old and new" (to the N.W. Sussex Growers' Mutual Aid Group)
November 17	G. F. Sheard J. J. Hesling Dr. N. W. Hussey	"Dutch horticulture" "Eelworms associated with mushroom culture" "Control of Phorids" (at the S.E. Region Horticultural Officers' Refresher Course at Sunningdale)
November 23	M. Hollings Dr. O. M. Stone	"Virus diseases of ornamental plants in Britain and the U.S.A." "Virus diseases of carnations" (at a meeting of the Association of Applied Biologists and the Horticultural Education Association in London)
November 25	Dr. N. W. Hussey	"Mushroom research at G.C.R.I." (at the Mushroom Growers' Association Area Meeting at East Grinstead)
December 4	A. C. Bunt	"The use of loamless composts" (to growers at Chobham, Surrey)
December 8	M. Hollings Dr. L. Broadbent	"Some properties and relationships of pelargonium leaf curl virus" "Tomato mosaic" (to the Association of Applied Biologists in London)

In addition, Mr. Sheard and Mr. Darby were members of a "Brains Trust" at a meeting of tomato growers organized by the N.F.U. and Farmers and Growers Industries Ltd., at Arundel on 25 January, and Dr. Broadbent took part in a similar function arranged by the N.W. Sussex Growers' Mutual Aid Group at Pulborough on 2 February.

Overseas visits

Once again the A.R.C. were generous in providing special travel grants to enable members of the staff to make overseas visits in the interests of their work.

Mr. Sheard, accompanied by Mr. R. Gardner, the Director of the Lee Valley Experimental Horticulture Station, spent two weeks in Holland, 5–19 March, visiting research centres and experiment stations, and growers' holdings. They obtained a wealth of information on the

Dutch glasshouse vegetable industry, and since their visit they have been much in demand giving an account of their impressions.

As already mentioned, Mr. Hobson was able to attend the Fifth International Congress of Biochemistry in Moscow and Mr. Hesling the Sixth International Symposium of Plant Nematology in Ghent.

Mr. Hollings also paid a short visit to Denmark, 11–15 July, with Mr. D. G. Frampton, for discussions on the raising of virus-free carnation stocks.

Other visits

As usual the staff paid many visits—too numerous to list in full—to other research centres and to growers' holdings in connection with their work. Mr. Darby was in Guernsey from 19 to 22 June inspecting trials with his new tomato varieties. Before taking up his post as Head of the Mycology and Bacteriology Department Dr. Last made a round of visits to Experimental Horticulture Stations and other places to acquaint himself with the problems on which his Department is likely to be engaged in the future.

Visitors

Visitors were as numerous as ever, and again included several large parties and many from overseas. Among U.K. visitors we were particularly pleased to see Sir Edward Salisbury, a former member of the Governing Body, who came on 20 November to discuss certain disease problems of ornamentals at Wisley.

Another large party of N.A.A.S. Horticultural Officers was received on 9 May, and the N.A.A.S. Advisory Plant Pathologists came on 14 June. The visit of the Pesticides Group of the Society of Chemical Industry on 23 June gave us special pleasure.

The full list of organized parties which visited the Institute, with the approximate number in the party where known, was as follows:

January 12	West Sussex Tomato Working Party (16)
February 1	West Sussex Tomato Working Party (14)
February 27	Men's Fellowship, Rustington Methodist Church (24)
March 21	French growers from Paris region (36)
March 24	West Sussex Flowers Working Party (11)
April 18	Staff and students from Kent Farm and Horticultural Institute, Swanley (4)
April 26	Staff and students from West of Scotland Agricultural College, Auchincruive (11)
May 1	Boys from Selsey County Secondary School (32)
May 4	Littlehampton Round Table (10)
May 8	St. James' Men's Fellowship, Littlehampton (20)
May 9	N.A.A.S. Horticultural Officers (64)
May 17	Mr. H. R. Haynes, N.F.U. London, with party from Holland (16)
May 18	N.A.A.S. Flowers Group (8)
May 26	N.A.A.S. Glasshouse Group (15)
May 27	West Sussex Teachers' Horticultural Society (15)

May 30	West Sussex Flowers Working Party (11)
June 6	Worthing Old Tablers Club (48)
June 8	Arundel Gardens and Allotments Association (44)
June 14	N.A.A.S. Advisory Plant Pathologists (31)
June 20	Haywards Heath Branch N.F.U. (32)
June 23	Society of Chemical Industry: Pesticides Group (16)
June 27	Dr. Bravenboer and party of Dutch advisory officers (8)
August 1	West Sussex Flowers Working Party (11)
August 30	Mr. Harald Eriksson and students from Horticultural Institute at Alnarp, Sweden (19)
September 19	N.A.A.S. carnation walk (40)

Overseas visitors came from as far north as Finland and from as far south as New Zealand, from as far east as Japan and from as far west as California. Thus has the name of the Institute spread far and wide throughout the world.

We were particularly pleased to welcome Dr. F. P. Pansiot, Horticulture and Viticulture Specialist in the Plant Production and Plant Protection Division of F.A.O., Rome. It was also a great pleasure to see once again Mr. E. R. Hoare, formerly of the N.I.A.E., who managed to find time to pay a brief visit on 16 September during the course of an extended tour through Africa, this country and the States; he is now Officer-in-Charge of the C.S.I.R.O.'s Irrigation Research Station, at Griffith, New South Wales, Australia.

The full list of overseas visitors was as follows:

Australia:	Mr. E. R. Hoare, Irrigation Research Station, C.S.I.R.O., Griffith.
	Dr. A. R. G. Lang, Research Officer, Irrigation Research Station, C.S.I.R.O., Griffith.
Canada:	Dr. W. B. Mountain, Canadian Department of Agriculture, Research Station, Harrow, Ontario.
	Mr. J. Smith, Provincial Horticulturist in the Okanagan Valley, British Columbia.
	Mr. Edward Sparkes, Kingsville, Ontario.
Denmark:	Mr. E. Bacher, Statens Vaeksthusforsog.
	Professor E. Hellmers, Royal Agricultural and Veterinary College, Copenhagen.
	Professor A. Klougart, Royal Agricultural and Veterinary College, Copenhagen.
	Mr. P. Neergaard, Plant Protection Service, Hellerup.
Eire:	Miss E. Conroy, Department of Plant Nutrition and Biochemistry, Johnstown Castle Agricultural College, Wexford.
	Mr. Garrett A. Fleming, Senior Research Officer, Johnstown Castle Agricultural College, Wexford.
	Mr. C. L. Masterson, Johnstown Castle Agricultural College, Wexford.
	Mr. John Seager, National Glasshouse and Vegetable Crops Research Station, Kinsealy.
	Mr. Gerald Spencer, Fruit farmer, Waterford.
	Mr. M. J. Woods, Agricultural Institute, Dublin.
Finland:	Dr. Frejvid Borg, Nadendal.
	Mrs. E. Tapio, Agricultural Research Centre, Tikkurila.
Germany:	Dr. Klaus Schmelzer, Institut für Phytopathologie, Aschersleben.
	Mr. Friedrich Trens, student.

Holland:	Ir. J. M. Andeweg, Institute of Horticultural Plant Breeding.
	Mr. J. A. v/a Berg, Naaldwijk.
	Mr. M. Groenewegen, Glasshouse Experiment Station, Naaldwijk.
	Mr. K. Olieman, Glasshouse Experiment Station, Naaldwijk.
	Mr. H. D. de Ruiter, Rotterdam.
	Ir. K. Szteyn, Institute of Horticultural Plant Breeding.
	Ir. G. P. Termohlen, Glasshouse Experiment Station, Naaldwijk.
India:	Mr. T. K. Bose, Royal Agricultural Horticultural Society of India, Calcutta.
	Professor P. K. Sen, Professor of Agriculture, Calcutta.
Israel:	Mr. Jacob Oppenheimer, Hagera Seed Growing Co. Ltd., Haifa.
	Messrs. J. N. Rosenblum and A. Regen, and Nova Boyhteen.
Italy:	Messrs. D'Atri Mario, D'Atri Attilio and G. Zuccorello.
	Dr. Vittorio Marzi, Director's Assistant, Agronomy Department, Universita Degli Studi, Bari.
	Dr. F. P. Pansiot, Horticulture and Viticulture Specialist in the Plant Production and Plant Protection Division of F.A.O., Rome.
Japan:	Dr. K. Tomaru, Plant Pathology Laboratory, Hatano Tobacco Experimental Station.
Kenya:	Mr. E. M. Chenery, Tea Research Institute, Kericho.
	Mr. G. D. Glynne Jones, Pyrethrum Board of Kenya, Wakaru.
Malaya:	Mr. G. H. Tinley, Rubber Research Institute.
Mauritius:	Mr. E. F. George, Sugar Industry Research Institute.
New Zealand:	Mr. R. Close, Crop Research Division, Christchurch.
	Mr. W. O. Roussel, Chairman of Vegetable Research and Extension Advisory Committee, Blenheim.
	Mr. Welch, glasshouse grower.
Nigeria:	Mr. J. A'Brook, Entomologist, Department of Agriculture, Northern Region.
	Mr. D. L. Downie, Deputy Director, West African Institute for Oil Palm Research.
	Mr. D. McDonald, Plant Pathologist, Department of Agriculture, Northern Region.
	Mr. I. Osayi, West African Institute for Oil Palm Research.
Poland:	Dr. Roch W. Doruchowski, Department of Vegetable Crops of the Institute of Soil Science and Cultivation of Plants.
South West Africa:	Mr. E. B. Mostert, Farm Manager, Anglo American Corporation of South Africa.
Sweden:	Dr. Lindsten, Kungl. Lantbrukshögskolan, Uppsala.
U.S.A:	Dr. G. H. Benham, American Agricultural Chemical Co., New York.
	Dr. H. M. Cathey, Plant Industry Station, U.S.D.A., Beltsville.
	Dr. Julius H. Freitag, Department of Entomology, University of California, Berkeley.
	Mr. A. O. Hansen, American Agricultural Chemical Co., New York.
	Mr. H. A. Robbins, Campbell Soup Co., Illinois.
	Dr. A. F. Ross, Cornell University.

In addition to the above Dr. G. Herklots, formerly Principal of the Imperial College of Tropical Agriculture in Trinidad, paid us a visit shortly before taking up his post as Government adviser on scientific matters in Nepal.

Meteorological observations

Meteorological observations were continued as in the previous year and are summarized in a table in the Appendix. Our readings have not yet been taken long enough to justify any

general comment, except perhaps to mention that after the extraordinarily wet year in 1960 the rainfall total was down to what we hope is nearer an average figure.

Acknowledgments

With pleasure we once again acknowledge the debt we owe to all those who have helped us with our work and development during the past year. To the Governing Body particularly for their unfailing support and encouragement, and to the Agricultural Research Council for their constant interest in our affairs, and for their advice and practical assistance given wherever possible and justified. The close liaison with the N.A.A.S. has already been mentioned, and we are grateful to the very many officers of that service who either at the experimental stations or in the counties have considerably facilitated our work and made its results known to growers.

Finally the Director again expresses his thanks to the staff, of all grades, whose good work has contributed to another successful year. The accounts of their work in parts II and III of this Report are very largely in their own words.

REVIEW OF RESEARCH

This review refers only to selected items of work carried out during the year which it is thought may be of more general interest, particularly to growers. It does not deal with the work of all the Departments, nor does it cover the whole field of work of those Departments which are mentioned. For a more complete account readers should consult the Departmental and Sectional reports and special papers which follow in Parts II and III of the Report.

It must be emphasized that much of the work is long term, and many of the results reported are of an interim nature; they may therefore require confirmation, often under different conditions, before firm conclusions can be drawn.

PLANT BREEDING

The Plant Breeding Section under Mr. L. A. Darby has continued its very active programme on the tomato, and with the appointment of an additional plant breeder it has been possible to extend it to include problems of disease resistance. The work on lettuce is also making excellent progress, and some of the new lines have aroused a great deal of interest among growers. Cucumber breeding proceeds at a somewhat slower pace, while a start has been made with collecting material for the programme designed to improve the winter hardiness of anemone.

Tomato

We reported last year the distribution of the compact-habit varieties for trial on commercial holdings during 1961, and we awaited with interest growers' experience with this new material. Nearly 500 growers received seed, in most cases of two varieties, but to our great disappointment less than one third of them returned the fairly simple questionnaire in which they were asked to record their experience. This made it difficult to assess the merits of the new varieties satisfactorily, and only general conclusions are possible. The full analysis of the data has not yet been completed, but Mr. Darby gives some of the main conclusions in his report. Not unexpectedly experience seems to have been varied, but it is a great encouragement that many growers found the new varieties suited them and proposed to grow them again. To some the compact habit of growth was a new thing, and not all knew how to manage it satisfactorily, with the result that there were many comments that strong growth could not be maintained

throughout the season. This was often because the new varieties were grown under unsuitable conditions, for which they had not been bred. There seemed to be general agreement that the new varieties set readily on the lower trusses and required less labour (for trimming, etc.) than usual, while fruit quality was generally considered to be good although some growers thought the fruits were rather small.

As we have emphasized, this new material represents only a first step in the production of better tomato varieties at the Institute, and already there are other new lines which are being put out for trials. It is obviously desirable for promising new material to be tested under commercial growing conditions at the earliest possible stage, and for this to be done in the main production areas of the country. Trials are therefore now conducted in a regular manner according to a scheme approved by the Governing Body. In the first year promising material, selected after careful observation and trial at the Institute, is issued to a panel of growers in each of the N.A.A.S. Regions of England and Wales, in Scotland and N. Ireland, and in Eire and Guernsey, and we are grateful to the advisory officers concerned for their co-operation in nominating the growers, for handling the seed, and for keeping an eye on the trials for us. At the same time, or perhaps even before, trials of the new varieties are conducted at the Experimental Horticulture Stations. If these trials prove satisfactory and show the new varieties to have real merit, they are then offered to the Institute's Subscribers for trial during the following year. Subsequently a wider distribution may be arranged, through the Tomato and Cucumber Marketing Board, for example, but eventually it is hoped to release the real winners to the seed trade through the established machinery of the National Institute of Agricultural Botany at Cambridge, although the necessary arrangements have yet to be settled with that body.

As reported last year three varieties were offered to the select panel of growers for trials on their holdings in 1961. The varieties were B738, a green-back free form of 'Ailsa Craig', B739, a similar form of 'Potentate', and B920, a compact-habit form of 'Moneymaker'. The reports received were sufficiently encouraging to justify a wider distribution, and in accordance with the scheme outlined above Subscribers to the Institute were offered seed of these varieties for trial during 1962.

Meanwhile, the breeding programme has continued at the Institute, and several trials were conducted in order to screen new straight varieties and F_1 hybrids. The yields Mr. Darby quotes in his report give every cause for satisfaction, and some varieties were outstanding. Crop yield over the whole season is not the main character of interest, however, and in all this work special attention is given to improving early yield and fruit quality, and to the habit of growth.

As mentioned, disease resistance is now also receiving attention. Tomato mosaic virus is one of the most serious disease problems the grower has to contend with, and as yet there is no sure means of controlling it by cultural methods, although our virus workers are pin-pointing the main sources of infection and showing the way in which infection can be minimized. The plant breeders have been collecting material for the disease resistance programme, and one of the more promising lines is one carrying a dominant character which prevents multiplication of the virus in the plant. Breeding programmes have been started to transfer resistance from this and other sources into standard commercial varieties and into new varieties bred at the Institute.

As previously reported, the John Innes Institute have heped us to make a flying start with work on breeding for leaf mould (*Cladosporium*) resistance by transferring to us for further development resistant lines of 'Ailsa Craig' and 'Potentate' bred at that Institute. Crosses have been made to transfer the compact-habit and even-ripening characters to these lines.

Cucumber

Cucumber breeding is still on a limited scale, but further work has been done to produce a type of 'Butcher's Disease Resister' with a shorter neck. A new line of work was started to attempt to deal with the problem of unwanted seed setting in glasshouse fruit.

Lettuce

The progress made with the lettuce breeding programme is beginning to arouse as much interest as the tomato work, but none of the lines has yet reached the same advanced stage—which would ensure uniformity and stablity—as the tomato varieties which have been issued to growers for commercial trial. In the programme designed to produce better-hearting varieties for growing in heated glasshouses during the winter fourth generation families were grown in trials at the Institute and at the Fairfield Experimental Horticulture Station, and selections were made to produce seed for a further generation.

The needs of the cold house grower are also receiving attention, and many existing varieties were screened at Stockbridge House Experimental Horticulture Station, Cawood, selections being made and sent to the Institute where they were potted for cross-pollinations to be carried out.

CHEMISTRY

The Chemistry Department, under Dr. G. W. Winsor, continued its work over a wide field, with the emphasis on studies of the nutritional requirements of some of the main glasshouse crops and outdoor chrysanthemums. Results are beginning to accumulate from the latter work, and they are being published as rapidly as possible.

Nutrition of glasshouse crops

It was explained last year that the experiments on crop nutrition are mainly of a long term nature, and are, for the most part, factorial experiments, that is to say, they investigate a number of factors (fertilizer treatments) and the possible interaction of one with another. They are accompanied by chemical analyses of the soil and plant material so that the responses to fertilizers can be assessed in relation to the initial fertility of the soil and their uptake by the plant. A good deal of work, statistical and chemical, thus has to be done before worth-while conclusions can be drawn, and the experiments must of course be allowed to run their full term.

Tomato

The main nutritional trial on the tomato in Block B, in which the effects of 72 fertilizer combinations are being studied, completed its first phase which had extended over four years. The trial was based on the variety 'Potentate', still very widely grown as an early crop in heated glasshouses, and was conducted for two seasons in steamed soil and for two seasons in unsteamed soil. (The trial is being continued in 1962 along the same lines, but with two other varieties).

The fertilizers whose effects are being studied in this experiment are nitrogen and potash (each at three rates), and phosphate, lime and magnesium (each at two rates). In 1961 there was a minor, but significant change in the treatments, the "nil" levels of nitrogen and potash being replaced by low levels of these nutrients. Previously the "nil" levels had given such poor growth as to be of little practical interest.

The yield data have yet to be analysed completely, but there appear to have been marked responses to all the main factors studied, other than magnesium. Liming again depressed yields,

particularly at the highest levels of nitrogen and potash. The voluminous data for the grading of the crop are also awaiting analysis, but the dominant nutritional factor again appears to have been potash, the proportions of fruit showing poor colouring being 78%, 39% and 27% (by weight) at low, intermediate and high potash respectively.

The experiment in which four different sources of nitrogen are being compared for use in liquid feeds was continued for a second year, but the crop was not as good as in the previous year. Nevertheless there was again a significant response, ammonium sulphate giving the best results both as regards crop weight and fruit quality.

A new line of work was the investigation of the effect of spraying urea on tomato plants infected with virus, undertaken in collaboration with the Virology Department. Previous experience had suggested that spraying with nitrogen in this form might be beneficial in stimulating the growth of the weakened plants.

The spray treatments used in one experiment consisted of 0·3% urea solution with or without 0·1% each of ammonium phosphate and potassium sulphate, these being compared with unsprayed control plots, the three treatments being tried on both steamed and unsteamed soil. All plants in the experiment were deliberately infected wih virus (TMV) when the second truss started to flower (13 March).

Although we had great hopes that this experiment would show a practical method the grower could apply to deal with an outbreak of virus, the results were disappointing. There did not seem to be any beneficial response to the urea sprays, as far as the appearance of the crop went, neither did the detailed recording and grading of the fruit show any marked response either to the spraying or to soil sterilisation, although final conclusions cannot be drawn until the data have been statistically analysed.

In a second experiment, plants were sprayed with 0·3% urea solution after infection with mild or severe strains of the virus (TMV), suitable controls being arranged. Again, the results were disappointing, spraying having no obvious effects on the plants. However, in this case the plants grew very vigorously, and it is still just possible that foliar spraying may be beneficial for plants making poor growth in soil which needs sterilizing.

Lettuce

The experiment testing the residual fertiliser effects on lettuce grown after tomatoes in the main nutritional trial in Block B was repeated, and again showed very marked differences between the treatments. Phosphate was the dominant factor, while the crop grew best at relatively low levels of nitrogen and was sensitive to acidity. Symptoms of manganese toxicity were less prominent than in the previous season, presumably because the soil had not been steamed for the tomato crop.

Carnation

The second nutritional trial, in which nitrogen and phosphate (each at four rates), potash (at three rates) and liming (at two rates) are being tested (96 treatments in all), continued satisfactorily during 1961, having been planted in May 1960. Marked differences in vegetative growth were evident from the various treatments, symptoms of nitrogen and potash deficiency occurring at low levels of these nutrients while the bottom leaves died on plants grown at the lower levels of phosphate. As in the previous trial increasing the nitrogen reduced the proportion of split calyces, and more splitting occurred in the limed than in the unlimed plots.

Chrysanthemum

The experiment with outdoor chrysanthemums was repeated for a second year, using the variety 'Orange Sweetheart'. Eighty-one fertilizer combinations, comprising dung, nitrogen, phosphate and potash, each at three rates, are included in the experiment, but the rates of dressing were somewhat modified for 1961. This experiment is being conducted in collaboration with the Horticulture Department, and a summary of the main effects is given in that Department's report.

Soluble salts in glasshouse soils

Work on the problem of soluble salts in glasshouse soils has continued, with the emphasis on the investigation of methods of determining their amount in a way which is not likely to give misleading results. The influence of soil texture on the method of determination was specially studied. Different methods under consideration were applied to some 50 soil samples from various parts of the country, the samples being chosen to include many old glasshouse soils having a high content of calcium sulphate which, in many cases, would have obscured the interpretation of the values obtained by the conventional *p*C test. The results of this investigation will be published later. During the course of it a promising improvement in technique suggested itself, and it would appear possible to develop a simple procedure for measuring the conductivity of soluble salts, other than calcium sulphate, directly.

Manganese and aluminium toxicities

Experiments on manganese toxicity, which as mentioned last year seems to be assuming increasing importance with a number of crops, were continued. The effects of lime and phosphate on its occurrence were tested in pots, using lettuce as the test plant, and several varieties of lettuce were grown in sand culture to determine their comparitive susceptibility to manganese toxicity.

In the course of one experiment some unusual symptoms were noted on the young lettuce plants. The damage only occurred at low *p*H values, and was much less pronounced when the phosphate level was high. The appearance of the symptoms, and the soil conditions under which they occurred, suggested the possibility of aluminium toxicity, and chemical analyses showed the likely importance of excess aluminium in the growth of lettuce. We thus appear to have another toxicity factor to contend with in glasshouse soils, and this may explain the unusually large response to phosphate found in nutritional trials at the Institute. There appears to be a distinct relation between the level of phosphate and the uptake of aluminium by the plant, and further studies are planned along these lines.

The composition of tomato fruit and its relation to quality and flavour

Much of the work of the Chemistry Department is devoted to studying the chemistry of tomato fruit with a view to determining the factors governing its quality and flavour. Most of the determinations are of the sugar content and acidity, these being the two components which are thought to have most influence on the taste of the fruit. A considerable number of such determinations are made during the year, and among the subjects receiving particular study are: the fruit composition of different varieties, the effect of environmental factors on fruit composition, the effect of manuring on fruit composition, the comparison of hormone-set fruit with that set naturally, and the effect of virus infection on fruit quality.

As regards varieties, the 1961 results supported the main conclusion of earlier years, that tomato fruit of different varieties, grown under similar conditions, differ most consistently in

their acidity. The studies of environmental factors are made on fruit from the cultural trial at the Lee Valley Experimental Horticulture Station at Hoddesdon, sponsored by the Institute, and for the 1961 investigations special arrangements had to be made for collecting it and transporting it to Littlehampton. Shading, watering and temperature were all found to affect the composition of the fruit, the highest acidity—probably the major factor in judging the taste of the fruit—being found in fruit grown under hot, shaded, dry conditions.

A new and important turn in the work was given by studying the effect of storage on fruit composition, again using fruit from the Hoddesdon experiment. It was found that the content of sugars, total solids and acidity all decreased during storage, the most consistent results being those for acidity. There is thus a clear indication that tomato fruit deteriorates—as far as its flavour is concerned—after picking, a result of considerable significance. This work is being continued in view of its extremely important practical implications concerning the storage life of tomatoes.

Further analyses on virus-infected fruit again showed that sugars and total solids were significantly increased by virus infection, the increase being apparently greater with a severe strain of virus as compared with a mild strain.

ENTOMOLOGY

Dr. N. W. Hussey and his colleagues in the Entomology Department are devoting most of their attention to mushroom pests and to the problem of red spider mite on cucumbers.

Mushroom pests

The "Worthing Phorid" (*Megaselia halterata*) was unusually abundant on commercial holdings in south-east England during the summer of 1961, and this provided an excellent opportunity for more intensified work on practical control methods in co-operation with local growers. The materials tested were aldrin, diazinon, malathion and synergised pyrethrins mixed in with the compost at rates of 10 or 50 parts per million before spawning. Diazinon proved the most promising, and was singularly successful on a local farm where Phorids had caused almost complete failure in several successive crops, the pest being almost eliminated when diazinon, as an emulsion, was mixed into the compost at 10 p.p.m. during machine-spawning. Yield from the treated crops was quite satisfactory.

To check, further, whether there were likely to be any damaging effects of diazinon on mushrooms a cropping experiment was carried out at the Institute. Yields were compared from beds where the insecticide had been incorporated at 10 and 50 p.p.m. in the compost, before and after peak heating, or in the casing. The yield, which reached two pounds per square foot, in six weeks, was unaffected by the treatment, but diazinon applied at the higher rate in the casing delayed the appearance of the flushes by three days. When mushrooms grown on compost treated at both concentrations after peak heating were analysed no residue of diazinon could be detected, so it appears that the use of diazinon in compost during spawning is sufficiently safe to justify large scale trials under commercial conditions.

Synergised pyrethrins are also proving of interest, and surface applications to newly-spawned compost were found to reduce the number of eggs laid. Experiments were initiated to test the value of liberating pyrethrins continuously into the atmosphere of spawn-running rooms by electrically-controlled aerosols.

Studies on the adult Phorid, *Megaselia halterata*, confirmed that almost all the infestation of a compost occurs within three weeks of spawning and if spawn running takes place in a fly-

proof structure egg-laying after casing is usually not enough to produce populations of larvae above the level (100 per 30 grammes of compost) which is considered likely to have an effect on yield.

Work has also continued on Cecids, and it has been found that the incorporation of aldrin in the casing at the rate of ten parts per million is unfortunately not satisfactory in controlling *Heteropeza*, although effective with *Mycophila*. Alternative methods of control have therefore been investigated, and the most promising seems to be to mix *gamma*-BHC in the casing at fifty parts per million, at which dose it does not appear to cause any harm to the crop. This type of experiment is difficult to conduct as the pest wanders readily from one treated bed to another, but in the first five weeks of cropping, before any large-scale migration had occurred, the treatment reduced the proportion of infested mushrooms from 80% to less than 10%.

A preliminary trial was done at the Institute to test the value of fumigating growing houses with methyl-bromide after cropping as an alternative to the "cooking-out" procedure, which may have a harmful effect on house structures.

Red Spider Mite

It is important to know the amount of damage from red spider mite that can be tolerated on a cucumber plant before spraying becomes necessary. Not only do growers naturally wish to keep spraying to a minimum on grounds of cost, but too frequent spraying is likely to encourage the development of resistant strains of the mite.

The effect of different degrees of mite damage on cucumbers was therefore studied by controlling populations on test plants for different periods. In a subsequent experiment (reported in a special paper at page 95), in which mite damage was simulated by removing portions of the leaves, it was shown that there is an interval of five weeks between leaf damage and the resulting reduction in crop, and using this information the critical populations of mites which led to a reduction in yield five weeks later were calculated for the various treatments. It was concluded that cucumbers can tolerate considerable mite populations without loss of yield, and it is intended to study this question further.

Investigation of the factors which induce red spider mites to go into the resting stage was continued, and an experiment was done to determine their natural migratory behaviour. The latter experiment confirmed that they are attracted towards the light.

We have been fortunate to obtain specimens of the predatory mite *Phytosieulus reigeli* from Holland; this mite shows promise of being a most efficient predator in glasshouses and holds out some hope of controlling red spider mite by biological means.

NEMATOLOGY

The Nematology Section, under Mr. J. J. Hesling, has completed its first year's work, the two subjects for study being mushroom eelworms and the stem and bulb eelworm on narcissus.

Mushroom eelworms

The types of eelworm which occur in the raw material of compost stacks have been studied. Eelworms have also been found in peat used as a casing material, and although the numbers may be few experiments have shown that they can multiply rapidly.

Special attention has been given to *Aphelenchoides composticola*, an eelworm which feeds on mushroom mycelium. In experiments with spawned compost in jars the population of this eelworm was found to build up to enormous numbers within the space of time that would normally be occupied by a mushroom crop. This eelworm was also found to withstand starvation for at least ten weeks, and some specimens may survive at least six weeks' drying. This ability to persist in adverse conditions suggests that the eelworm may be carried in water or even blown about on dry compost or casing material.

Bulb eelworm

The first step in the work on bulb eelworm was to develop a technique for assaying eelworms, using onion seedlings which they readily infect when inoculated into the tissues. The invasion of narcissus bulbs when planted in eelworm-infested soil has been studied, and the effect of different numbers of eelworms inoculated into or close to narcissus bulbs has been investigated. Observations have also been initiated on the occurrence of the eelworm in the field. All this work is in its preliminary stages, of course, and will need to be carried a good deal further before firm conclusions can be drawn .

MYCOLOGY AND BACTERIOLOGY

As reported under staff changes Mr. P. H. Williams retired on 30 September and was succeeded by Dr. F. T. Last who did not, however, take up his duties at the Institute until 1 December. Dr. Last was able to give some attention to his future work before arriving at the Institute, and made a number of visits to meet advisory officers and growers, particularly in the eastern counties, to learn something of the problems of the industry. A revised programme for the Department was prepared for the A.R.C. Visiting Group, and in view of its emphasis on microbiological aspects of disease problems it is proposed to extend the name of the Department to include bacteriology and mycology in future. The main lines of work will be the study of soil sterilization, either with steam or chemicals, in its relation to soil-borne disease problems, especially of the tomato (e.g., Corky Root and Brown Root Rot, *Didymella* Stem Rot, *Verticillium* Wilt, etc.), and the investigation of problems associated with the cultivated mushroom, particularly "Watery Stipe" disease and those involved in the composting process. Work will be continuing on Petal Blight ("scorch") and Ray Blight of chrysanthemum, and at a later stage it is hoped to resume the study of powdery mildews and take up work on bulb diseases.

The following notes refer to work carried out during the year, before the new direction given to the research programme.

Verticillium Wilt

Further experiments were done on the *Verticillium* Wilt disease of tomatoes, to investigate the effect of growing conditions on symptoms caused by the two species of *Verticillium*, *V. albo-atrum* and *V. dahliae*, which are known to be implicated in this disease. Shading and temperature, the two factors which growers immediately resort to manipulating when troubled with the disease, were studied particularly, and differences were observed in the behaviour of plants infected by the two fungi, thus showing the importance of knowing which fungus is involved in an outbreak of the disease.

Experiments with the *Verticillium* Wilt of carnations (caused by *V. cinerescens*) to determine its persistence in the soil have had to be discontinued because the control plots became contaminated, but evidence was obtained to suggest that the fungus can survive for at least

two years in soil planted with non-susceptible crops, e.g., tomato and chrysanthemum. Infectivity did, however, seem to decrease rapidly in the absence of a susceptible host, and if infected plants were removed six months before replanting subsequent spread of the disease was slower than after immediate replanting.

Petal Blight of chrysanthemum

The weather conditions and other factors which favour infection by the fungus (*Itersonilia perplexans*) causing "scorch" or Petal Blight of chrysanthemums have been the subject of preliminary experiments. The host range of the fungus has also been studied, and cross-inoculation experiments were done with isolations of the fungus from various sources.

"Watery Stipe" disease of the mushroom

After a rather quiet spell, during which little was heard of it, there have been further outbreaks of the disease which for want of a better name we have hitherto referred to as "Watery Stipe". The past year's experience has confirmed the view we have held all along that this disease is a very serious potential threat to the industry, and those growers who have suffered from it will know only too well, from the loss of crop sustained, that it is one of the most serious troubles they have to contend with.

All this lends point to the work on the disease which has been pursued steadily, if unspectacularly, since the "eruption" in 1957, which caused a near panic in the industry. The disease has proved a most intractable problem, and matters are complicated by the lack of consistency in visible symptoms, the only certain way of recognizing the trouble being the loss of crop which accompanies them. An important advance was achieved when Miss Gandy was able to demonstrate the transmission of the disorder, which indicated that an infectious principle was involved. Subsequently the work has concentrated on determining the nature of the infectious principle, and some of the difficulties experienced were mentioned last year. There were strong indications that the infectious agent might be a virus, but no virus was known to infect a fungus, and although all the refinements of technique which have been evolved in connection with our work on the virus diseases of ornamentals were applied to the "Watery Stipe" problem, it soon became clear that the methods used would need to be modified when dealing with the mushroom as a possible host for a virus. Much tedious work has been required, often handicapped by a lack of material, and at times it has proved most frustrating. However, all this effort, in which Miss Gandy, of the Department whose work is being described, and Mr. Hollings, of the Virology Department, have co-operated most closely, has at last had its reward, and as will be evident from the special report at page 103 a tremendously important and exciting breakthrough has been achieved. There now seems little room for doubt that the disease we have been studying is caused by a virus which *can* be transmitted (although not necessarily always is) by the anastomosis, or joining, of the hyphae of the mushroom. The critical experiment was to show that the disease could be conveyed to healthy mushroom beds by inoculating them with a purified preparation from diseased mushroom, *containing no living mushroom material.* This provided the crucial evidence needed to show that the very suggestive virus-like particles seen under the electron microscope in preparations from diseased mushrooms were indeed most probably virus.

Obviously this vitally important discovery will need confirmation by further inoculation experiments, but even then it will be by no means the end of the road. We shall have to find out how the virus is normally transmitted, and the possibility that insects may play a part in this will particularly need to be investigated. Perhaps even more important, it will be necessary to conduct a survey of the incidence of disease and determine whether all of the outbreaks observed

are due to the infectious principle, that it to say, are transmissible, or whether different disorders are involved. The difficulty here is that it takes a long time to determine transmissibility by the usual culture methods in the laboratory, and what is required is some new technique which will permit a rapid diagnosis of a disease outbreak. The hope here is to develop a serological technique of the kind that has proved so useful in our work with ornamentals, and much effort is now being devoted to this.

This section appears under the heading which has previously been used in these reports, but it will be seen from the special article written by Miss Gandy and Mr. Hollings that it is now proposed to give the name "Die-back" to the disease referred to. This relates to the progressive deterioration or dying back of the mycelium which seems a more characteristic feature of the disease than the many other symptoms described in the past. It is perhaps unfortunate that yet one more name should be added to the long list—"La France", "Mummy", "Brown", "Watery Stipe", and "X-disease"—which has been used for this type of disorder, but the situation has at least been clarified to the extent that "Die-back" applies only to that diseased condition of the mushroom which is caused by a transmissible infectious agent with the virus-like properties described in the article by Miss Gandy and Mr. Hollings.

VIROLOGY

The Virology Department under Mr. M. Hollings has had another very full year's work, despite the fact that progress is hindered by the delay in providing the special glasshouse and laboratory facilities required. However, as will be seen from the administrative section of this Report, these facilities are now well on the way.

Dr. L. Broadbent, the Head of the Plant Pathology Division, continues his work on the epidemiology of tomato mosaic.

Carnation viruses

Much of the work of the Department is concentrated on the carnation, as this crop is subject to a complex of diseases which must be unravelled, and the plant has proved a very suitable subject for the development of techniques which can be applied generally to the virus diseases of ornamentals.

The wide-spread carnation mottle disease has been found to infect many other plant species besides the carnation. The ringspot virus has an even wider host range, although it appears to spread less readily in carnation. The intensive studies on mottle virus, now almost completed, are being applied to ringspot. Other carnation viruses are also receiving attention, including etched ring which was first described last year. Conclusive evidence has now been obtained from transmission experiments that etched ring is due to a virus. The progress of this disease in cuttings taken from infected plants has been observed, and the symptoms were found not to appear until some four months after the cuttings had been taken; thus to eliminate etched ring roguing must be delayed until the plants are well grown.

Carnation mottle virus cannot be eliminated by heat treatment, but during the course of work on the use of heat treatment for producing virus-free clones of carnation it was found that an "attenuated" form of mottle virus sometimes survived in tip cuttings from treated plants which were at first thought to be virus-free. These results, which are described in detail in a special article at page 100, emphasise the need for thorough and repeated testing of carnations raised from tip cuttings before they are claimed to be virus-free.

Further efforts have been made to raise virus-free plants by heat treatment and tip culture. The technique for rooting the tips has been improved, and more tests have been done to map the concentration of mottle virus in growing tips. As explained above there is some risk of the occurrence of a not readily detected attenuated virus in the course of this work, but some clones of four varieties of carnation, obtained by tip culture, have shown no symptoms of virus for up to a year, and repeated indexing did not detect in them any of the eight viruses for which reliable tests exist. Thus the production of truly virus-free plants of carnation appears at long last to have been achieved.

Chrysanthemum viruses

In order to develop a quicker serological technique for detecting chysanthemum stunt than the standard grafting test on to the variety 'Mistletoe' further attempts have been made to purify the virus, so far without success. The variety 'Blanche' which has been used as an indicator plant in the United States has proved unreliable and very inferior to 'Mistletoe' under our conditions.

By contrast, it has been possible to purify aspermy virus quite readily although normally present in lower concentration than stunt in the chrysanthemum.

Tomato mosaic

Intensive work has continued on the epidemiology of tomato mosaic. Many more commercial tomato crops, thought to be infected with virus, have been surveyed with the help of N.A.A.S. officers, and of 203 samples of foliage sent in during 1960 and 1961, 187 were found to be infected with a strain of tobacco mosaic virus (TMV) different from the strains found in smoking tobacco. Although nearly all brands of cigarette or pipe tobacco or cigars tested were infected with virus it is clear that smoking tobacco is rarely a source of TMV in British tomato crops. In fact, in the survey of commercial crops mentioned, only in four samples of foliage from grafted plants on one nursery was a tobacco strain of the virus detected. Thus there is always a risk of virus being transmitted to tomato plants from tobacco, and although the risk may be small growers would be well advised to take suitable precautions.

The importance of seed as a source of virus has received further attention, and seed contamination has been found to be a more complicated matter than was at first thought. Acid cleaning is not always effective in eliminating virus from infected seed, and it appears that tri-sodium orthophosphate only inhibits virus and does not inactivate it, so that if the chemical is washed off after treatment the virus re-appears. More experiments have confirmed that virus is normally only transmitted to seedlings from infected seed during pricking out, and not if the young plants are not disturbed.

Further observations have been made on the occurrence of virus in crops after the soil has been sterilized in various ways. It appears that while careful steaming eliminates virus from the soil, the use of chemical sterilizers, such as metham-sodium or chloropicrin, is more likely to lead to the early infection of the crop.

No evidence was obtained that virus is carried over on the structure of the glasshouse during the winter, but it may persist for many months on workers' clothing if stored away in the dark.

It has been suggested that spraying virus-infected crops with urea may be of benefit in improving the growth of the crop, and two experiments were conducted in collaboration with the Chemistry Department to test this. These experiments have already been described above,

in the section dealing with the work of the Chemistry Department, and it need only be repeated here that the weekly spraying with urea appeared to have no significant effect on virus disease symptoms or on the crop.

Another experiment was done to obtain an estimate of the loss in yield from infection by tomato mosaic, this time in a cold house at the Efford Experimental Horticulture Station. Virus caused a loss of crop of the same order as recorded in the similar experiment at the Institute in the previous year, as well as a loss of marketable fruit due to blemishes, but the plants were rather lush and unbalanced in their growth and it may be they responded in a way that would not normally be the case under ordinary commercial conditions. The experiment is to be repeated for two more years.

CROP PROTECTION

The Crop Protection Department, under Mr. W. H. Read, has devoted much of its attention to the very important problem of Glasshouse Red Spider Mite, but further work has been done on soil sterilisation, as well as on the control of Cucumber Mildew, Chrysanthemum Petal Blight and Narcissus Leaf Scorch.

Red Spider Mite

Last year we reported that in an experiment planned to test various materials for the control of red spider mite on cucumbers the pest had failed to build up to the expected levels, and it was thought this might have been due to the use of sulphur vapour for the control of mildew. This was followed up in 1961 by an experiment designed to see if sulphur could in fact provide a satisfactory control of red spider mite. Two rates of application were tried, one gramme and one-quarter gramme per thousand cubic feet of glasshouse volume nightly in two separate glasshouses, with a third untreated glasshouse serving as a control. It soon became apparent that the higher rate of application was too damaging to the plants, and the dose was therefore reduced to half a gramme per thousand cubic feet nightly. The population of mites in the three houses was assessed by two alternative methods, and it was found that although there were fewer mites on the plants subjected to sulphur vapour the mites were nevertheless present in sufficient numbers to cause severe injury to the plants. The prolonged vaporisation of sulphur at the higher rate of half a gramme per thousand cubic feet nightly also appeared to cause some hardening of the plants. Thus the promise shown by sulphur vapour as a control measure for red spider mite has not so far been confirmed.

A number of new chemicals have been tested in the search for acaricides which are effective against strains of mite proving resistant to materials at present in use. Several grades of polybutenes, which act through their stickiness, were also tested. Details of the tests and of the results obtained are given in Mr. Read's report. All that can be said at this stage is that some of the materials tested show sufficient promise to justify further work on them. Analytical work has been carried out in the laboratory to determine the residues likely to be left on cucumber plants after spraying with one of the promising compounds (thioquinox).

Some recently-introduced organo-phosphorus compounds were also tested against red spider mite on carnations, and for details of the tests reference should again be made to Mr. Read's report. Of particular promise was oxydemeton-methyl which was found to be about twice as potent as the commonly used demeton-methyl; it was also equally persistent and had the great advantage of leaving no unpleasant smell on carnations shortly after spraying.

Resistance to Kelthane has been investigated in the laboratory, and has required the development of a technique for estimating small degrees of resistance to this compound. During

the course of this work a strain of mite 50 times more resistant than the parent mites was selected, showing the extent to which resistance to Kelthane can build up.

Soil sterilisation

The long-term soil sterilisation experiment in houses C1–2 was run for a third year, with the same two varieties, 'Potentate' and 'Moneymaker', as in the previous year. Although yields were somewhat lower, partly because the crop was pulled out earlier, they were in line with those previously obtained. The three sterilisation treatments, steam, chloropicrin and metham-sodium, again gave very much better yields than where the soil had not been sterilised, but there was nothing to choose between them. The figures are given in Mr. Read's report.

A careful examination was made of the roots of the plants in this experiment, and it was found that there was significantly less corky root and brown root rot on plants from the steamed plots than on those from plots treated with metham-sodium, although all sterilisation treatments resulted in significantly less root disease than in the unsterilised control plot. From observation of growth differences at different stages in the experiment it appeared that roots in the sterilised plots became diseased later than those in the unsterilised control plots, possibly because of re-infection of the soil from below.

Further work has been done in the laboratory on the chemical determination of very small amounts of methyl isothiocyanate, the compound liberated by metham-sodium in the soil. A method, suitably modified to deal with certain problems which had arisen, has been successfully used to study the persistence and distribution of methyl isothiocyanate residues in the soil after various methods of treatment. The greatest depth of penetration was obtained where a solution of methyl isothiocyanate was applied to the bottom of the trench as digging proceeded.

The injury likely to be caused to tomato plants by the products resulting from the decomposition of metham-sodium in the soil has been studied, and a simple chemical method for detecting traces of methyl isothiocyanate, the compound most concerned, in the air has been devised. The usefulness of this test for indicating when tomatoes can be safely planted out in glasshouses treated with metham-sodium or methyl isothiocyanate is being investigated.

Cucumber Mildew

Large-scale trials in which sulphur was vaporised nightly at the rate of one ounce per 50,000 cubic feet of glasshouse space confirmed the preliminary results obtained in the previous year. The use of sulphur at this rate gives good control of mildew but appears to harden the plants and may cause some scorching of the leaves near the vaporisers When the rate was reduced to half that mentioned the control of mildew was inadequate.

As red spider was also not controlled at the higher rate of sulphur vaporisation (see earlier paragraph) alternative methods of controlling mildew are desirable, and some of the new compounds tested against red spider have also been examined for their value in controlling mildew.

A method of rooting detached cucumber leaves has been used to obtain uniform material for precise spraying tests.

Chrysanthemum Petal Blight

Trials with fungicides for the control of chrysanthemum Petal Blight (or "scorch"), caused by the fungus *Itersonilia perplexans*, have frequently failed in the past owing to the difficulty of obtaining infection of unsprayed blooms. A method of providing conditions suitable for infection has therefore been devised, and trials have begun to assess the efficiency of

fungicides applied in various ways. Zineb, 0·1%, applied at high volume at two-day intervals showed most promise, but caused some spotting of the outer petals of the variety 'Penrod'.

Narcissus Leaf Scorch

Further study has been made of the biology of the fungus *Stagonospora curtisii*, which causes Leaf Scorch on narcissus.

In the trials with fungicides the addition of an emulsified polyvinyl acetate slightly reduced the injury caused by Bordeaux mixture and improved the protective action of zineb.

HORTICULTURE

The pattern of work in the Horticulture Department, under Mr. G. F. Sheard's leadership, has been set and was outlined last year. The only new work attempted was a preliminary study of the problem of "weak neck" in roses as a prelude to a wider programme on the more general question of improving the life of cut flowers.

Tomato growth

The experiment in which sowings had been made at weekly intervals over a whole year (22/9/1959 to 11/10/1960) was completed during 1961, all plants having been allowed to grow to an age of about twelve months. The rate of development of the above-ground parts of the plant was measured every week for each of the fifty-six successive sowings.

The data on fruit development have been analysed and form the subject of a special report in Part III. The work showed that fruiting takes place in five phases which are influenced, as regards their duration, by daylength. There is a "dormant" condition, when the plant appears to make little or no progress towards fruiting, and dormancy is only broken when the days become longer than the night, that is, at the spring equinox. This phenomenon is of course true of many plants, and Dr. Cooper has been led to speculate whether there may not be a general type of interaction between the daylength response curve of a plant and the curve of natural change in daylength, which may govern winter dormancy.

During the year an experiment was done to investigate the relation between fruiting and vegetative growth. Many growers hold that with the tomato there must be a certain balance between the amount of fruit and the amount of leaf on the plant, but there is almost no precise information on this point. In the experiment plants were treated in a variety of ways, three de-leafing treatments being tried with four de-fruiting treatments in all combinations. Weekly measurements were made of the growth of the various organs of the plant. All plants suffered a check in growth as soon as the first fruits began to swell, but the check was not related to the amount of fruit on the plant as it occurred equally on plants which were not allowed to bear any fruit at all, the flower buds being removed as soon as they were formed. The data have not yet been fully analysed, so further conclusions cannot yet be drawn, but it was evident that the treatments markedly altered the form of the plants, though not the rate of vegetative growth.

A complementary experiment was done on de-leafing, to compare the effect of the amount of de-leafing done in normal commercial practice with the effect of half and double that amount, the control treatment being one in which the leaves were not removed until they were dying. A preliminary examination of the results, which have yet to be analysed statistically, suggests that yield was undoubtedly reduced by de-leafing.

Last year we referred to experiments conducted over two years at the Institute to test, among other things, the value of the commercial practice of root restriction, as achieved by

growing plants in "whalehide" pots, in controlling the growth of the tomato. In 1961 a further experiment was done to compare the effect of different degrees of root restriction, using 4-in. or 9-in. "whalehide" pots, with or without polythene sheeting under them. The results indicated that the more the roots were restricted the better the chance of producing a satisfactory flower truss in the dormant period, whereas the setting of the truss seemed more likely to be controlled by other factors, such as temperature and humidity.

Mushroom investigations

A second series of experiments has been done in the special apparatus developed for studying the growth of mushrooms under controlled conditions. Four ventilation rates, two temperatures, high and low humidity, and the interaction of these factors have been studied. An increase in the number of cabinets to 16 is planned in order to make it possible to investigate finer differences between the treatments.

Mr. D. Cooke, of the Statistics Section, and Mr. P. B. Flegg have continued to collaborate in their efforts to reduce variability in mushroom experiments, and it has been found that uniformity can be improved to some extent by using equal weights of spawn for each experimental tray. In the course of this work information was obtained on the effect of spawning rate on cropping, and as this is of practical value to growers the experiments have been reported in a special article at page 118. Briefly, the results showed that increasing the rate of spawning led to earlier cropping and higher yields, and at current market prices the better returns more than met the additional cost of the spawn. It is suggested that a high rate of spawning may ensure a reasonable yield from a poor compost.

Further experiments, also in collaboration with Mr. D. Cooke, have been done on the effect of stage of picking on the crop and on the appearance of the flushes, and a relation has been established between the yield of untrimmed mushrooms and the stage of maturity at picking.

In any study of the cropping of the cultivated mushroom special interest attaches to the conditions governing the development of the thickened mycelial strands from which the mushroom primordia originate. Work on this subject has now been in progress for three years and is shortly to be reported elsewhere. Some of the conclusions are mentioned in the Horticulture Department's report.

As a development of the work on the variability between experimental plots, experiments have been carried out to see whether variability can be reduced by an improved watering technique which ensures a more uniform and constant level of moisture in the beds than is possible with the usual hand watering at two to three day intervals, with its inherent wetting and drying cycle. Absorbent wicks laid across the beds from a water reservoir have been tried as a means of watering the beds by continuous capillarity. The method shows promise, and is being tested not only for its possible commercial application but also as an experimental technique for investigating the moisture requirements of the casing layer.

Loamless composts

The preliminary studies of peat-sand mixtures as plant composts dispensing with loam indicated very clearly that the nutritional aspects, that is to say, the correct incorporation of fertilisers, were likely to be all-important if such composts were to be of practical value, particularly during the difficult period of the year. Accordingly, the work during the past year has concentrated on this subject, and a series of experiments was conducted to determine the amounts of nitrogen, phosphate, potash, lime and magnesium required in the base fertilizer

of a compost made up of a 3:1 mixture of sphagnum peat and fine sand. The experiments were comprehensively planned to study all the main interactions of the fertiliser treatments, and were repeated regularly over the year to study seasonal effects. Among the test plants used were tomato, spinach, antirrhinum and cucumber.

During the summer the plants grown in all mixtures were quite normal. In the winter, however, there was a marked interaction between nitrogen, phosphorus and calcium, and various growth abnormalities were observed if these elements were out of balance. Provisional recommendations are made for the amounts of fertilizers containing these elements to be added to the compost during the winter and will be found in the Horticulture Department's report.

The different sources of nitrogen for use in peat-sand mixtures are being compared, as hoof and horn is becoming increasingly suspect as a source of trouble in such composts. The addition of minor elements appears to reduce the trouble from abnormalities, and this question is receiving special attention. Boron seems to be the most important single element.

In the course of the work on loamless composts antirrhinum has been widely used as a test plant, although difficulties in raising antirrhinum in composts containing loam, when the loam has been steamed, are well known in commerce. It has however been possible to develop a virtually trouble-free method of raising antirrhinum seedlings which growers are recommended to try where they have experienced trouble in the past, and details are given in the Horticulture Department's report.

Carnation: planting density and date of planting

The combined planting density and date of planting trial, started in July, 1960, has been continued, the last of the four plantings being made in March, 1961. Some of the early results are given in the Horticulture Department's report, but they should be regarded as providing no more than a provisional indication of the way things are going in this experiment.

Chrysanthemum manuring

The manurial experiment on outdoor chysanthemums, conducted in collaboration with the Chemistry Department, was repeated, with the same 81 fertilizer combinations, although the rates of dressing were modified in 1961 to cover a wider range. The treatments had a smaller effect on bloom size and stem length than in 1961, the greatest effect being produced by phosphate and potash in advancing the cutting date. A comparison of the 1960 and 1961 results suggests the possibility of a seasonal influence on the response of chrysanthemums to manuring.

NURSERY MANAGER'S REPORT

by

J. M. EVANS

The field trial glasshouses

Building development

The area of glass was increased by approximately 8,000 sq.ft. in the autumn by the erection of five aluminium alloy glasshouses as follows:—

1. *Plant breeding glasshouses.* Four houses (each 57 ft. x 30 ft.) were donated by the States of Guernsey to increase tomato breeding facilities. They will be equipped with small-bore high-speed hot water heating, automatic ventilation and automatic watering. In three of these four houses growing will be carried out in the borders, while the fourth will be compartmented and used for growing plants in pots on benches.

2. *New propagating glasshouse.* The fifth house has been erected to make good the deficiency in propagating facilities mentioned in previous reports. It is 100 ft. x 20 ft., orientated E–W, and constructed to give maximum transmission of low angle winter sunlight. Here, too, automatic ventilation will be fitted in due course.

In order to improve the efficiency of working in the potting shed a concrete Dutch barn and lean-to has been erected to the north of it. This will provide covered storage for loam, implements, boxes, staging, etc., and will facilitate the internal re-organisation of the potting shed.

Heating system

The new boilers were commissioned in October, and the new pipe systems in the glasshouses are being progressively linked to the new distribution mains. Blocks D and E and propagating house no. 4 were completed at the end of the year, and work was proceeding on Blocks B, F and C. Owing to unavoidable delays it is unlikely that the changeover will be completed before the summer of 1962.

The warning system was extended to include the new boilers.

General cropping

Steam sterilisation was carried out wherever possible on the nursery prior to the season's cropping, and peat was again applied to the border soil at the rate of 15 tons per acre. In our experience peat is the only bulky organic material to give a worthwhile improvement in physical condition on the difficult brick earth on which the nursery is built. Little effect has so far been noticed on soil *p*H.

Tomatoes

Tomato yields have again increased. This was most noticeable in Blocks F and G, where yields exceeding 90 tons per acre (on a basis of 14,000 plants/acre) were recorded on some

varieties. The earliest crop was in Block F, where picking began on 12 April and ended on 16 September. The hitherto low nutritional levels in Block B were raised for the 1961 season, resulting in increased tomato yields and a reduction in the incidence of *Botrytis* reported last year. Reductions in both yield and quality were recorded in glasshouses where tobacco mosaic virus experiments were carried out and where the virus was intentionally introduced either artificially by inoculation or by the leaving of "unsteamed" plots in otherwise "steamed" houses.

Where possible, hygiene precautions were taken to prevent the spread of TMV into "clean" houses and a good measure of success was achieved in limiting the spread until mid-summer. *Cladosporium* was evident and required control, but no other pest or disease was of consequence until TMV became widespread later in the season.

Cucumbers

The first crop (variety: 'Butcher's Disease Resister') in houses A2–6 was grown for an experiment on the control of Red Spider Mite and was planted on 21 February. Yields were low because of a high infestation of the mite in many plots and a hardening of growth as a result of some of the control measures used.

Houses A1 and A7 were allocated to the Plant Breeding Section for further trials and only carried the one crop.

A second crop was taken, using the variety 'B.D.R.', in houses A2, 5 and 6 as a trial on bed composition. It was evident that the addition of sphagnum peat improved growth and root run both within the bed and in the border soil beneath. As a result of this preliminary trial peat will be used in 1962 in an effort to improve the physical condition of our cucumber beds.

Carnations

Carnation house E1 was again used for small-scale research projects.

Houses E2 and E3 cropped for their second year in excess of expectation, both in quantity and quality. Disease was of very low incidence in E2, but in E3 *Verticillium* wilt caused the loss of two large blocks of plants and is likely to terminate the trial prematurely in spite of efforts to minimise its spread.

Lettuce

Seed was produced from selected plants, and the new variety 'Southdown 5B' was screened for mosaic virus.

Heated winter crops were taken from Blocks B and G.

Research glasshouses and mushroom unit

In readiness for the completion of the new Plant Pathology Division research glasshouse unit, and because of increasing commitments, staff was increased and a new charge hand appointed.

Outside field trials

Early chrysanthemums

The factorial nutritional experiment was run for a second year on the same site using the variety 'Orange Sweetheart'.

Anemones

A small planting of anemones was made for the Plant Breeding Section.

Bulbs

Work on bulbs, outdoors and under glass, is being continued.

Reserve land

Fencing of the 41 acres of permanent ley to the south of the railway boundary was completed, the grazing being let to a local farmer.

Windbreaks

A number of × *Cupressocyparis leyandii* and *Quercus ilex* were planted for future windbreaks. The *Escallonia* 'Crimson Spire' hedge along the southern boundary grew well.

Unfortunately the anchorage of the *Cupressus macrocarpa* planted in 1957/8 is poor and these trees will eventually be replaced by the planting of *Pinus radiata* and *Quercus ilex*.

II. RESEARCH SUMMARY: DEPARTMENTAL & SECTIONAL REPORTS

1. PLANT BREEDING

by

L. A. DARBY

Tomato

Off Institute trials

Nine hundred and thirty-eight packets of seed of the compact-habit tomato varieties GCR2–25 were distributed to 479 growers for trial in the 1961 crop, and the growers were subsequently invited to answer a questionnaire pertaining to these varieties. The overall response was poor with only 31% of the growers returning questionnaires. There was a marked variability related to geographic location, e.g., 80% of the growers in Guernsey who participated in the trials completed questionnaires, but from the N.A.A.S. Eastern region, which includes the Lea Valley, only 18% responded.

It was hoped that the trials would enable a fuller appraisal to be made of these varieties with a view to selecting the best, but the meagre data on some due to the poor response from growers make this difficult. However, the following conclusions can be drawn.

In general vegetative characters, fruit setting and labour requirements there were no marked differences between the varieties. Seed germination was average-high, rogue production was average-low. Plant vigour was generally described as just right or a little too weak, and a majority of growers agreed that their plants maintained satisfactory growth through the season. Growth is very much influenced by the grower's cultural conditions and methods, but in spite of advice (e.g., *Rep. Glasshouse Crops Res. Inst. 1960*, page 45), the varieties were often tried in unsuitable environments, and this frequently led to disappointing results. There was considerable agreement that the varieties set readily on their bottom trusses, and that the labour requirement was less than usual.

Early and total yield are very much influenced by time of planting and management, so again it is not possible to make valid intervarietal comparisons with so few data available. For early crop (first four weeks) the varieties averaged from 1·0 to 1·9 lb. per plant, whilst overall the range was from less than 1·0 to more than 2·5 lb. per plant. The average total yields ranged from 6·3 to 10·0 lb. per plant for varieties, with individual growers reporting between 4·0 and 17·0 lb. per plant.

The information obtained on fruit quality tends to confirm the predictions that within the sequence GCR5–25 the lower-numbered varieties gave smaller fruit with better shape and colour. All varieties were given a good rating for firmness, and flavour was generally considered to be better than average.

As anticipated, *Botrytis* and tomato mosaic virus were the most troublesome diseases though no marked varietal differences in susceptibility were detected.

Growers were asked to state whether they intended to grow these compact-habit varieties in 1962; 74% replied in the affirmative, whilst 26% indicated that they had no further interest in this present series of GCR varieties.

From the data no strong preferences or dislikes for the different varieties were detected; in fact there were good and bad reports on all of them. Many growers expressed the view that after their experience in 1961 they would be more successful during 1962 in growing the compact-habit varieties as they need to be grown.

Although these trials have not permitted a complete assessment of the varieties GCR2–25, they have confirmed that a section of the industry is keen to exploit varieties which combine yield and high fruit quality with restricted vegetative growth. The series GCR2–25 does not represent the end point in the compact-habit breeding programme; further improved varieties which incorporate freedom from green-back and *Cladosporium* resistance are already undergoing their first trials.

Three other new varieties were also distributed to a select panel of growers for trials on commercial holdings in 1961 (see *Rep. Glasshouse Crops Res. Inst. 1960*, page 45). The varieties were B738, a green-back free form of 'Ailsa Craig', B739, a similar form of 'Potentate', and B920, a compact-habit form of 'Moneymaker'. The co-operating growers were invited to complete a questionnaire in order to record their opinions of these new varieties. The questionnaire was designed to ascertain whether the back-cross programmes, which were intended to transfer the single characters mentioned into the three pre-existing varieties, had been successful.

In general the respondents agreed that the new varieties were similar to their recurrent parents with only the specific characters mentioned showing any great difference in expression. One exception to this was that several growers considered B738 to be smaller fruited than their own 'Ailsa Craig', although by contrast others were very well satisfied with its fruit size. This criticism suggests that the 'Ailsa Craig' used at the Institute to develop B738 was itself a small fruited line, and this will be investigated in 1962.

The overall opinions of these three varieties were sufficiently encouraging to warrant a more widespread distribution of seed for trials in 1962 and this was effected via the Institute's Subscription Scheme.

New varieties bred at the Institute were also tested in trials at Efford, Fairfield and Stockbridge House Experimental Horticulture Stations, Terrington Experimental Husbandry Farm, Cleppa Park Horticultural Demonstration Station, and the N.A.A.S. East Midland Headquarters at Shardlow Hall. These trials will be reported in the annual reports from the various centres. J. W. M. Smith sponsored an observation trial on tomato grafting at Stockbridge House E.H.S., and this also is described in that station's report.

Institute trials

Further trials were conducted at the Institute in order to screen new straight varieties and F_1 hybrids. Crop culture always followed standard commercial methods with N–S rows, 13½ in. between plants, and the plants trained in Guernsey arches. There were always five replicates, and four or six plants per plot depending on the space available for each trial. In spite of TMV infection all plants made satisfactory growth and adequate yields were achieved.

In an early trial 20 new compact-habit varieties were compared, cultural details being as follows:—

Seed sown	29/11/1960
Planted	16/2/1961
First harvest	20/4/1961
Crop cleared	14/9/1961

The average yield over all varieties was 14·5 lb. per plant. 'Baby Lea' gave 14·1 lb., 'GCR12' yielded 14·5 lb. and a new F_1 hybrid 'J165' gave 16·6 lb. per plant.

In a second trial 20 varieties with tall spreading habit were grown in one house with 20 compact-habit varieties in an adjacent house:—

Seed sown	13/2/1961
Planted	6/4/1961
First harvest	30/5/1961
Crop cleared	26/9/1961

The yields from the tall spreading varieties ranged from 10·7 to 15·2 lb. per plant, whilst the compact varieties varied from 10·2 to 17·4 lb. per plant.

In a third trial, ten tall spreading varieties were compared with the ten corresponding compact editions of the same varieties. The latter have been bred in back-cross programmes which have transferred the compact-habit character from 'Baby Lea' into several pre-existing commercial varieties.

In order to reduce inter-plant competition which would suppress the yields of the compact varieties if grown amongst the tall spreading varieties, and also to facilitate the individual management of the two groups, they were grown in separate but adjacent houses of the same glasshouse block. Within the two groups valid intervarietal comparisons can be made, but the comparison of varieties in different groups must be tempered with the knowledge that they had small differences in their environments. Cultural details were as follows:—

Seed sown	28/2/1961
Planted	13/4/1961
First harvest	16/6/1961
Crop cleared	29/9/1961

The tall spreading varieties yielded from 12·0 to 15·3 lb. per plant and the compact varieties from 12·0 to 16·3 lb. per plant.

Disease resistance (A. C. Hastie)

Tomato mosaic virus. Several lines of the cultivated tomato which had been obtained from the U.S.A. were tested with a strain of TMV which had been isolated locally. The plants were exposed to both natural and manual infection, and the degree of infection was subsequently assessed by visual symptoms and local lesion tests with *Nicotiana glutinosa.*

The most promising material is a line carrying the dominant allele TM_2, for this prevents multiplication of the virus in the plant. It has not yet been determined whether TM_2 confers any protection against fruit damage in those plants bearing fruit at the time of inoculation.

A pure breeding line in which resistance is determined by three independent loci also conferred some resistance to infection as well as a considerable tolerance of infection. Although this tolerance has been described as due to recessive alleles (Walter, 1956), they also gave some protection against the local strain of TMV in heterozygotes.

Breeding programmes have been started to transfer resistance from these and other sources into standard commercial varieties and new varieties being developed at the Institute.

Cladosporium fulvum. Resistant lines of 'Potentate' and 'Ailsa Craig', developed in back-cross programmes at the John Innes Institute, were tested and found to resemble the recurrent parents in agronomic characters. Further crosses have been made to introduce compact-habit and even-ripening into these genotypes.

Cucumber

Further selections and back-crosses were made in the programme to shorten the neck on

fruit of 'Butcher's Disease Resister', and a new project was initiated to introduce gynoecious sex expression into the same variety. This latter character would eliminate the problem of unwanted pollinations in the parthenocarpic varieties grown under glass in Britain.

Lettuce

F_4 families were grown at the Institute and at Fairfield Experimental Horticulture Station during the winter of 1960/1961, and further selections made for improved winter-hearting varieties. F_5 seed was obtained.

As a prelude to a new breeding programme for the production of better cold house varieties, many existing varieties were screened at Stockbridge House Experimental Horticulture Station Selected plants were sent by post to the Institute where they were potted and cross-pollinations made.

Anemone

Small plots of anemone varieties were grown in order to gain experience of this crop in readiness for new breeding projects.

REFERENCE

WALTER, J. M. (1956). Hereditary resistance to tobacco mosaic virus in tomato. *Phytopathology*, **46,** 513–6.

2. PLANT PHYSIOLOGY

by

E. R. LEONARD

The one-eighth h.p. motor installed in the line of west ridge ventilators in the research glasshouse has proved of adequate power. It is quieter in operation, has negligible over-run—so that the ventilator movement does not "hunt", and has been provided with fuse and overload protection unit whereby, it is anticipated, the motor and ventilator actuating mechanism will be protected against damage. This was not possible with the previously installed quarter-horsepower motor. It is hoped to provide the other lines of ventilators with similar motors and protective gear as funds and labour permit.

The annex to the laboratory block has been provided with the tools necessary for constructing and testing the special equipment required for the Department's work. The Technical Services Unit was still occupied on some of the structural alterations at the end of the year.

Soil moisture tension control and the growth of young tomatoes (H. R. B. Hack)

An improved design of auto-irrigator cell has been tried out and has proved satisfactory in operation. There has been no repetition of the erratic cracking found with the previous model.

The plants in this experiment showed abnormal growth which was independent of soil moisture level. Spectrographic analysis of the plant material, kindly undertaken by the Soil Survey at Rothamsted Experimental Station, gave no clear indication of mineral excess or deficiency. Experiments have been carried out which have determined that the abnormal growth was the result of toxicity originating from the tubing through which water was supplied to the system.

The use of tensiometers in growth experiments (H. R. B. Hack)

Records of soil moisture tension variability from which patterns of water uptake may be inferred have been collected in previous years and have been examined further. Statistical analyses are being carried out within the Department, or, where the accumulation of data is large, by the electronic computer of the Rothamsted Statistics Department. The results form a basis for estimating ranges of tension which can be defined in tomato borders with different numbers of tensiometers suitably located, and hence of experimental tension treatments which can usefully be compared.

Environmental observations (H. R. B. Hack)

Records of solar radiation, giving intensity and totals integrated over pre-determined periods, of air, plant, and soil temperatures, and observations of soil moisture tension were made in connection with the experiment on soil moisture control. A description of the method of solar radiation measurement and a discussion on its accuracy in relation to certain problems within glasshouses have been published.

A system has been devised whereby the number of points of observation (by thermocouple) recorded by a potentiometer can be multiplied, at the cost of decreased frequency of observation. This has been in use for recording soil temperatures in the plant containers, where the rate of change of temperature is slower than in air. The system has the advantage that the uniselector stepping does not have to be kept in synchronisation with the potentiometer channel selection.

Each uniselector step is coded and the code fed to the potentiometer.

The continuous system of conversion of potentiometer records to punch tape for subsequent analysis by computer has been under trial. The apparatus has resulted in considerable saving of time in the calibration of solarimeters (by comparison with a sub-standard checked at Kew Observatory). Various components of the system comprising the recording potentiometer and the analogue-digitiser have required modification by their respective manufacturers, and tests are continuing as time permits.

"Root restriction" trials (E. R. Leonard)

A preliminary test of technique for investigating the different environmental factors imposed on tomatoes growing in pots as contrasted with growth in the border has been made. Seedling tomatoes at about the normal stage for planting out were grown in two different sizes of pots and in the border, the pots being either stood on the surface or sunk in the soil. Records were taken of the soil temperature in the different environments and of the soil moisture tension. The treatments will require considerable amplification and repetition with different dates of planting and at different temperatures before data can be obtained on which the effect of the nexus of the environmental modifications can be interpreted in terms of plant growth, and, in particular, of the production and development of the lower trusses.

3. CHEMISTRY

by

G. W. WINSOR

Studies on the nutrition of glasshouse crops, and on the composition and biochemistry of tomato fruit, have been continued throughout the year.

An outline of the nutritional work in progress is given in the next section. Publication of the results recently completed is receiving urgent attention. The return of Mr. J. H. L. Messing from British Guiana in 1960 has enabled the studies on manganese toxicity to be expanded considerably, and has also led to the recognition of yet another toxic factor, namely aluminium, in the soil at the Institute.

The important subject of tomato fruit quality is being examined not only in terms of the nutritional aspects but also by means of studies on the main taste components of the fruit. Considerable experience has been gained in the interpretation of routine fruit analyses. Completion of these studies should ultimately provide basic information on the effect of nutritional, environmental and other factors on this aspect of fruit quality. The work is supplemented by more detailed investigation of some individual constituents of tomato fruit.

Considerable progress has been made in biochemical studies on the pectic enzymes of the tomato, particularly with regard to polygalacturonase activity in normal and "blotchy" fruit.

Nutritional trials with glasshouse crops (G. W. Winsor and M. I. E. Long)

The results from the main nutritional trial with tomatoes (Block B), referred to in the next section of this report, complete the first phase of this investigation, consisting of a study of the manuring of variety 'Potentate' for two seasons in both steamed and unsteamed soil. The data will be published when the analytical and statistical work is completed. The trial will be continued in 1962/63 with two different varieties on a "split-plot" basis.

The results of the first trial on the liquid feeding of tomatoes via trickle irrigation equipment have now been published (*J. hort. Sci.*, **36,** 1961, 254–67), and a further trial on alternative sources of nitrogen in liquid feeds completed its second season.

Two trials on the effect of foliar sprays containing urea on tomato plants infected with virus (TMV) were conducted in collaboration with the Virology Department.

Two experiments on the nutrition of winter lettuce were concluded in Block B during 1961, the 1960/61 crop being harvested in February and the 1961 crop in December. Lettuce appear to be highly sensitive to soil conditions. Thus, in addition to the occurrence of symptoms of manganese toxicity in some plots, it now appears that aluminium toxicity may constitute yet another complicating factor (*cf.* the results obtained by J. H. L. Messing and reported on page 55).

The second of a series of nutritional trials with carnations, planted in May, 1960, was continued throughout 1961. Marked responses to the nutritional treatments were noted, and, in addition, the higher level of liming induced boron deficiency.

A study of the manuring of early outdoor chrysanthemums (variety: 'Orange Sweetheart') was continued in collaboration with the Horticulture Department.

Experiments on the nutrition of tulips in sand culture were sponsored at the Kirton Experimental Husbandry Farm. Considerable analytical work was carried out at the Institute on bulbs from these studies.

A revised scheme for grading tomatoes from the nutritional trials was adopted for 1961. The best fruit was classified by the Institute graders according to the Tomato and Cucumber Marketing Board standards. The remaining fruit was sub-classified as in 1960 into categories NUC/A–Z as approved by the A.I.C. Glasshouse Working Party, except for the sub-division of category NUC/Z as "mild" or "severe".

$3^2 \times 2^3$ factorial nutritional trial with tomatoes (Block B)

The treatments in this long-term experiment consist of three levels each of nitrogen and potash in factorial combination with two levels of phosphate, magnesium sulphate and lime (carbonate), making a total of 72 plots. The plants, of variety 'Potentate', were set out in steamed soil on 14 March. The only change in procedure from previous seasons was that the "nil" levels of nitrogen and potash were replaced by low levels of these nutrients.

Soil samples were taken for analysis from all 72 plots in April, June, September, and again in October after planting the succeeding lettuce crop. The mean analytical data at the first date of sampling are given for comparison with previous reports:—

Potassium levels "Available" potash (K_2O)	*K1* 0·020%	*K2* 0·065%	*K3* 0·144%
Phosphorus levels "Available" phosphate (P_2O_5)	*P1* 0·007%	*P2* 0·091%	
Nitrogen levels Nitrate-nitrogen	*N1* 12 p.p.m.	*N2* 26 p.p.m.	*N3* 76 p.p.m.
Liming levels *p*H	*Ca1* 6·3	*Ca2* 7·2	
Range of pC values (2.5:1 aqueous suspensions)	2·51—3·47		

The heights of all plants were measured in June, as in preceding years. Statistical analysis of the data shows that phosphate, and to a lesser extent nitrogen and potash (up to the K2 level), increased the height of the plants, whereas liming significantly decreased it ($P = 0{\cdot}001$). An adverse effect of lime on the growth of tomato plants at the Institute has been noted previously, both with regard to height and yield.

Data for yields and grading of the fruit have been sent to Rothamsted for statistical computation. The total yields ranged from 7·4 to 12·2 lb. per plant, and showed marked responses to all nutritional factors other than magnesium. Liming again depressed yields, particularly at the highest levels of nitrogen and potash.

The extensive data for grading of the crop have not yet been examined fully, but the dominant nutritional factor was potash, as in previous years. Thus the proportions of fruit showing irregular pigmentation in any form were 78, 39 and 27% by weight at low, intermediate and high potash respectively.

Two complete sets of leaf samples were taken for chemical analysis during the season, and these are now being examined. Only the results for manganese in the foliage during June are as yet completed, these ranging from 106 to 1022 p.p.m. in the dried tissue. Lime and phosphate significantly reduced the manganese content, whereas nitrogenous fertilizers increased it.

These results are in accordance with the visual symptoms of manganese toxicity observed in the second half of the season. Manganese toxicity was not a serious problem in this year of the trial, however, and it may be noted that the application of lime, whilst eliminating toxicity symptoms, appreciably depressed the yields.

Comparison of four sources of nitrogen in liquid feeds (House C4)

An experiment in which urea, ammonium sulphate, ammonium nitrate and a mixture of potassium and sodium nitrates are compared as alternative sources of nitrogen for the tomato crop, started in 1960, was continued in the same form for a second season. The nitrogen content and potash/nitrogen ratio were kept equal in all four treatments at any one stage of growth.

The mean yields per plant and proportions of irregularly coloured fruit (including very mild forms) were as follows:—

	Yield (lb. per plant)	*Irregularly coloured fruit* (%)
Urea	9·8	43·3
Ammonium sulphate	10·6	35·7
Ammonium nitrate	10·0	39·1
Potassium and sodium nitrates	9·6	45·0
Least significant difference at P=0·05	± 0·43	± 3·1

Both total yield and fruit quality were less satisfactory than in the preceding season. Ammonium sulphate gave the best results, the yield being significantly higher and the proportion of irregularly ripened fruit lower than from any of the other three treatments. The lowest mean yield and poorest quality were obtained where potassium and sodium nitrates were applied, but in neither respect was this treatment significantly worse than that supplying urea.

Both the ammonium salts produced considerable soil acidity near the trickle nozzles, whereas the mixture of potassium and sodium nitrates induced alkalinity.

The experiment will be modified in 1962, the new treatments including replacement of sodium nitrate by calcium nitrate.

Foliar application of nitrogen, phosphate and potash to virus-infected tomato plants in steamed and unsteamed soil (House D1)

In the course of a nutritional trial in 1957, when the plants were making pale, weak growth in unsteamed soil and showing symptoms of virus (TMV), foliar sprays containing urea were applied as a possible corrective measure throughout the houses. The condition of the plants improved considerably, but it was not known whether the foliar sprays contributed to this recovery.

An opportunity to study the effect of foliar sprays arose in 1961, when replicated trials were laid down in collaboration with the Virology Department. The spray treatments consisted of 0·3% urea solution with and without 0·1% each of mono-ammonium phosphate and potassium sulphate, these being compared with control plots (unsprayed). The three treatments were replicated six times, and each plot was "split" for steamed and unsteamed soil. The layout took into account possible residual effects due to high and low potash levels in the four preceding seasons. All plants, of variety 'Potentate', were infected with virus (TMV) by the Virology Department when the second truss started to flower (13 March).

Visual assessment of growth in April and May showed some slight improvement from steaming, but this tended to disappear as the season continued, indicating that even the unsteamed

soil was in relatively good condition. No beneficial response to urea sprays was apparent, although scoring of the plants in April and May suggested some slight but short-lived response to urea in combination with phosphate and potash.

Detailed recording and grading of the fruit failed to show any marked response either to foliar spraying or to soil sterilisation, but final assessment of the results must await statistical examination of the data. The vigour of the plants was undoubtedly checked by infection with virus. The main ripening disorder noted was "green-back"; the overall proportion of fruits showing obvious vascular trouble was relatively slight, and the amount of "waxy" fruit was negligible. Total yields from steamed and unsteamed plants were 11·1 and 10·9 lb. per plant respectively.

Foliar application of urea to healthy and virus-infected tomato plants (*House D2*)

A further trial (see preceding section) on the effect of foliar sprays containing urea on tomato plants was conducted in house D2, again in collaboration with the Virology Department. Two spray treatments (0·3% urea solution and control, unsprayed) were applied to tomato plants of variety 'Moneymaker' receiving three virus treatments (uninfected, mild and severe TMV), the six combinations being replicated four times.

Spraying with urea had no obvious effect on the plants, which were excessively vigorous. The possibility remains, however, that foliar spraying might be beneficial for plants making poor growth in soil needing partial sterilisation.

Virus infection reduced the total yields from 12·6 to 11·4 lb. per plant (both virus strains combined), without appreciably affecting the proportion of saleable fruit. Treatment with virus had some effect on sub-classification of the unevenly ripened fruit, including a reduction in the overall proportion of "waxy" fruit for the season by the "severe" strain, but detailed statistical analysis will be necessary before the results can be evaluated. Some of the "control" plants unfortunately became infected during the season.

$3^2 \times 2^3$ factorial nutritional trials with lettuce (*Block B*)

Studies on the nutrition of winter lettuce (variety: 'Cheshunt 5B'), started in 1959, have been continued. The crop planted in November, 1960, was harvested in February, 1961, and the data both for yields and for nitrogen, phosphate and potash content of the plants have since been examined statistically. The results are too extensive to be considered here in detail, but will be prepared for publication in due course.

Phosphate was again the dominant nutritional factor in this trial. The response to phosphate, averaged over all other combinations of treatments, both favourable and unfavourable, is illustrated by the following data:—

	Level of phosphate	
	P1	*P2*
Hearted lettuce (%)	13·1	56·7
Saleable lettuce (%)	68·6	80·8
Mean weight per plant (*oz.*)	0·72	2·00

The crop grew best at relatively low levels of nitrogen, and was sensitive to acidity. The lowest level of potash (K1) had an adverse effect on growth. Symptoms of manganese toxicity, though present in some plots, were far less prominent than in the preceding season, the soil not having been steamed for the tomato crop of 1960.

There is reason to think that yet another factor besides managanese toxicity may be operative in this trial. Following investigations by J. H. L. Messing (see page 55), this factor may well prove to be aluminium toxicity, occurring at low, but not at high, levels of phosphate.

A further crop of lettuce was planted in October, 1961. A proportion of the plants was, unfortunately, damaged by selective weed-killer during propagation. Although many of the plants originally affected grew out of the condition by the time of harvesting, it will be necessary to repeat the trial in its present form during 1962/63.

$4^2 \times 3 \times 2$ factorial nutritional trial with carnations (*House E2*)

This trial, started in May, 1960, was continued during 1961. The treatments include four levels each of nitrogen and phosphate in factorial combination with three levels of potash and two levels of liming. The varieties planted are 'William Sim' and 'Pink Sim'. The early stages of the trial were referred to in the Annual Report for 1960.

Marked differences in vegetative growth resulted from the various combinations of manurial treatment during 1961. The symptoms of nitrogen and potash deficiency occurred at low levels of these nutrients, and the bottom leaves died on plants grown at the lower levels of phosphate. Symptoms of boron deficiency were diagnosed in some plants and confirmed by chemical analysis of the foliage. From the distribution of symptoms in the plots, and from analyses of the leaves, it appears that this condition of boron deficiency was induced by liming.

The data for flower production and bloom quality have not yet been examined fully, but the results for one variety ('William Sim') up to the end of October show beneficial responses to the higher levels of phosphate and nitrogen. The proportion of split calyces decreased progressively from 17·5% to 6·4% with increasing levels of nitrogen, confirming the trend observed in the previous trial. More splitting occurred in the limed than in the unlimed plots, but whether this is associated with induced boron deficiency is not yet known.

Factorial nutritional study with early outdoor chrysanthemums

This trial, started in 1960 in collaboration with the Horticulture Department, was continued during 1961. The treatments include three levels each of dung, nitrogen, phosphate and potash in factorial combination, making a total of 81 plots.

The levels of application of fertilisers were modified for 1961 on the basis of soil analyses during the preceding year, including an increase in the top levels of nitrogen, phosphate and potash. The plots were also limed, raising the mean *p*H to 6·0 as compared with the unexpectedly low value of 5·3 in 1960. Despite these changes, the levels of soil phosphate were still relatively low by mid-summer, again indicating rapid fixation of added phosphate in the Institute's soil.

Visual assessment of growth in all plots in June, and again in July, showed a beneficial response to increasing levels of all four treatments. Symptoms of potassium deficiency developed where this nutrient was omitted in the presence of adequate levels of nitrogen and phosphate.

As compared with 1960, the blooms in 1961 were generally of smaller size, with rather short stems, but matured at an earlier date. The crop records, compiled by the Horticulture Department, have been sent to Rothamsted for statistical computation; in the meantime a summary of the main effects is included in the report of the Horticulture Department (see page 92). Leaf samples, taken in July, will be analysed early in 1962.

Soil salinity studies (D. M. Massey and G. W. Winsor)

Studies on the effect of soil texture on the relation between plant growth and salinity, started in 1960, were continued in the first half of 1961. Mixtures of soil with varying proportions of peat and sand were used to provide different water-holding characteristics in the growing medium. The test plants were lettuce, grown in 6 in. pots.

Considerable data have been obtained concerning the effect of soil texture on the relation between salinity measurements by the various techniques. Thus, for example, the water-holding characteristics of the soil have a marked effect on saturation paste extracts, whereas the conventional 2·5:1 soil suspensions are largely independent of soil texture. Interpretation of the growth responses shown by the lettuce plants was complicated by decreases in soil salinity during the period of the experiments, despite very careful attention to avoid leaching soluble salts from the pots and limitation of the trials to relatively short periods of growth. Furthermore, these losses of soluble salts were related to soil texture, being greatest in soil-sand mixtures and less marked where peat was present. Further investigation was accordingly deferred until improved facilities could be provided, using either non-porous containers without drainage or far larger volumes of soil so as to confer more stability in soil salinity levels as compared with small pots. The second alternative has since been chosen, and a series of small concrete beds is now under construction, including facilities for collection of any drainage for analysis.

During the second half of the year the opportunity was taken to compare the results obtained by different methods of salinity determination in a range of some 50 soil samples from various parts of the country, the samples being chosen to include many old glasshouse soils having a high content of calcium sulphate. The co-operation of members of the National Agricultural Advisory Service in obtaining these samples is gratefully acknowledged. Many of the samples contained sufficient calcium sulphate to interfere seriously with the interpretation of the results of the conventional method of assessment in 2·5:1 aqueous soil suspensions. The results of this investigation will be prepared for publication in due course.

Whilst measuring the calcium sulphate content of the soil samples referred to in the previous paragraph by a procedure published by the United States Salinity Laboratory, involving precipitation by acetone, the possibility of adding acetone when making routine conductivity measurements in aqueous soil suspensions was also considered. Highly promising results were obtained from preliminary studies, and it would appear possible to develop a simple procedure in which the conductivity of soluble salts other than calcium sulphate is measured directly in aqueous acetone. The addition of acetone reduces the electrical conductivity of a salt solution, but this effect can be offset by the use of larger electrodes. Careful attention has been given to co-precipitation of calcium and potassium sulphates at high concentrations of the latter salt.

Manganese and aluminium toxicities (J. H. L. Messing)

Manganese

The effects of lime and phosphate on the occurrence of manganese toxicity have been studied in factorial pot experiments, the test plants being lettuce (variety: 'Cheshunt 5B' except where stated otherwise). The soil used was a fairly acid silt loam of the Hamble series at this Institute; the initial *p*H was 5·7, falling to 5·4 on steam sterilisation and to 4·6 after addition of peat (20% by volume) and fertilisers. Several varieties of lettuce were also grown in sand culture in order to compare varietal susceptibility to manganese toxicity. Graded concentrations of manganese were used in the latter trial, thus giving further information on the relation between the occurrence of toxicity symptoms and the manganese content of the plants.

The water-soluble and exchangeable forms of manganese in the soil were found to be closely correlated (r = +0·94), but there appears to be an abrupt change in the form of the relationship at about *p*H 6. The sum of these two forms of manganese is probably the best measure of availability in acid soils, but above *p*H 6 the water-soluble category is to be preferred. More than 3 p.p.m. of water-soluble manganese, or 25 p.p.m. in exchangeable form, are considered likely to produce toxicity symptoms in lettuce grown in this soil.

The availability of manganese is closely associated with soil *p*H, and is thus likely to be influenced by any factor affecting *p*H. The effect of added phosphate on the categories of manganese determined in the soil was relatively slight, and could be attributed largely to the consequent changes in soil acidity.

The manganese content of lettuce grown in sand culture was directly related to the concentration of this element in the nutrient solution. In soil-grown plants the content of manganese was highly correlated with the sum of the water-soluble and exchangeable fractions; correlation coefficients of + 0·91, 0·97 and 0·99 were obtained in three experiments covering a wide range of conditions. The relation between the manganese content of the plants and the occurrence of toxicity symptoms was similar in both soil and sand-culture. Varietal differences were apparent, however, 'Newmarket' being particularly tolerant and 'Golden Queen' highly susceptible.

Aluminium toxicity

In the course of an experiment designed to study manganese toxicity some unusual symptoms were noted on the young lettuce plants. Necrosis at the base of the oldest leaves was followed by collapse and wilting, the symptoms being quite unlike those associated with manganese toxicity. The damage only occurred at *p*H values below 5·3, and was much less pronounced at a high level of phosphate. The appearance of the symptoms, and the soil conditions under which they occurred, suggested the possibility of aluminium toxicity. Determinations of exchangeable aluminium in the soil, and of the content of aluminium in the lettuce plants, were therefore made on samples from a factorial trial which included three levels of lime and two of phosphate. The content of exchangeable aluminium in the soil was found to be closely correlated with yield ($r = -0{\cdot}86$, significant at $P = 0{\cdot}05$).

An attempt was made to study the effect of aluminium concentration on the growth of lettuce in sand culture. Mild toxicity symptoms, accompanied by about 10% reduction in yield, resulted at the highest concentration of aluminium applied (10 p.p.m. in the nutrient solution). Analysis of the foliage of these plants showed only 60 p.p.m. of aluminium in the dried tissue, however, as compared with 270 p.p.m. in severely affected plants grown in soil without lime or phosphate. It seems probable that the adequate level of phosphate in the nutrient solutions prevented excessive uptake of aluminium. Further studies are planned, using younger plants grown at graded levels of phosphate and aluminium in factorial combination.

Analysis of lettuce from the nutritional trial in Block B (see page 52) showed a marked accumulation of aluminium in plants grown without added phosphate, values above 900 p.p.m. of aluminium being found in some instances. This result may help to explain the unusually large response to phosphate found in the nutritional trials, and further collaborative studies will be undertaken.

Tomato fruit quality and composition (G. W. Winsor and J. N. Davies)

Studies on some factors affecting tomato composition have been continued during 1961 with particular reference to sugar content and acidity, these being the main taste components of the fruit. The subjects examined included:—

(a) The composition of fruit of seven different varieties.

(b) The effect of environmental factors on the composition of the fruit of two varieties.

(c) Changes in fruit composition during storage.

(d) The composition of tomato fruit in relation to manurial treatment.

(e) The composition of fruit from virus-infected and uninfected plants, with and without foliar sprays containing urea.

(f) Comparison of the composition of the free juices, walls and whole fruit of hormone-set and naturally pollinated tomatoes.

The fruit examined under headings (b) and (c) was obtained from the Lee Valley Experimental Horticulture Station at Hoddesdon, all other samples being from trials at the Institute. The data are too extensive to be discussed here in detail, but some of the main results are outlined in the sections which follow.

The composition of different varieties of tomato

The following seven varieties were grown for the continuation of studies on the composition of different varieties of tomato:—

A.	'Potentate'	E.	'L.M.R.1'
B.	'Ailsa Craig'	F.	'Delicious'
C.	'Moneymaker'	G.	'Radio'
D.	'E.S.5'		

The experimental plants occupied the guard plots adjoining the outside of Block B, each variety being replicated five times. Samples of the best quality fruit obtainable were collected on ten occasions between early June and September for analysis of the expressed sap.

Statistical analysis of the data for the titratable acidity of the expressed sap showed highly significant differences between varieties. Similar studies in previous years showed that 'L.M.R.1' was the most acid variety studied, whereas 'Potentate' and 'Moneymaker' were among the least acid varieties. These results have been confirmed in 1961, the mean values ranging from 7·8 and 7·9 milliequivalents of acid/100 ml. sap for varieties 'Potentate' and 'Moneymaker' respectively to 10·1 for variety 'L.M.R.1'.

Variety 'Ailsa Craig' showed the highest content of total solids and reducing sugars in the expressed sap, but the differences between varieties were small and not statistically significant. The mean sugar content of the fruit rose appreciably from early June to mid-August.

The results obtained in 1961 support the main conclusion of earlier studies; tomato fruit of different varieties, grown under similar conditions, differ more consistently in acidity than in total solids or sugar content.

The effect of some environmental factors on fruit composition

Studies on the effects of temperature, shading and watering on the composition of tomato fruit were continued and extended during 1961, using varieties 'Potentate' and 'Moneymaker'. The fruit was again kindly supplied by the Director of the Lee Valley Experimental Horticulture Station from an experiment sponsored by the Horticulture Department. Previous difficulties in the transport of tomatoes by post or rail, often involving delay and damage, were avoided by collection of the samples in a specially fitted suitcase by members of the Institute staff. Samples

of the best quality fruit available from each variety were obtained on eight occasions between the end of May and the beginning of August.

The environmental factors previously studied in this investigation (temperature, shading and watering) are now combined factorially with three levels of potash applied in solution via an irrigation system. Samples for the fruit composition studies were obtained from the lowest (K1) and the highest (K3) potash levels. The differential potash treatments did not, however, produce the expected differences in soil potash status, and no significant effects on fruit acidity were observed. Changes in the rates and method of application of fertilisers have been recommended for 1962.

The content of sugars in the expressed sap of both varieties was significantly decreased by shading and increased by the drier watering regime. The acidity of the fruit was significantly increased both by shading and by the higher temperature, as shown in the following mean values, expressed as milliequivalents of acid per 100 ml. of expressed sap:—

	'*Moneymaker*'	'*Potentate*'
Hot	7·7	7·4
Cool	6·8	6·7
Significance (P)	0·001	0·001
Shaded	7·7	7·3
Unshaded	6·7	6·8
Significance (P)	0.001	0·001

The highest acidity in both varieties was found in fruit grown under hot, shaded, dry conditions. The effect of the various treatments on the acidity and sugar content of the expressed sap was reflected in the results for the total solids. In particular, the total solids content of the expressed sap of both varieties was significantly increased by the drier watering regime.

Continuation of these studies throughout the period of the Hoddesdon experiment should yield much valuable information concerning the effect of environmental factors on the main taste components of the tomato.

The effect of storage on fruit composition

Preliminary investigations have already shown that the acidity and sugar content of tomato fruit changes during storage (*J. Sci. Fd Agric.*, **13,** 1962, 108–15). Further studies were made during 1961, using fruit of variety 'Moneymaker' from the experiment referred to in the preceding section. Fruit from the various environmental treatments was stored at constant temperature for either seven or nine days after harvesting. Analyses of three sets of samples, each containing fruit from sixteen treatments, were completed during the season.

The content of sugars and total solids, and the acidity and refractive index of the expressed sap, all decreased during storage. The most consistent results were those for acidity, the decrease on storage being significant at $P = 0{\cdot}01$ in June and at $P = 0{\cdot}001$ in July and August. The decrease in sugar content was significant at $P = 0{\cdot}001$ in both June and July. The results for both total solids and refractive index were significant at $P = 0{\cdot}05$ on two out of the three sampling dates.

A significant interaction between the effects of glasshouse temperature and subsequent storage was also found in the results for fruit acidity. The decline in acidity during storage was greater for fruit grown at the higher temperature. Interpretation of this result is, however, com-

plicated by the observation that the acidity of fruit grown at the higher temperature was significantly greater than that grown at the lower temperature. In addition there was a considerable degree of correlation between the titratable acidity of the fresh samples and the decrease in acidity during storage (correlation coefficient $r = 0{\cdot}55$, significant at $P = 0{\cdot}001$); the higher the initial acidity, the greater in general was the decrease during storage.

This study will be continued in view of its practical implications concerning the storage life of tomatoes.

The effect of steam sterilisation and of sprays containing urea on the composition of fruit from virus-infected plants (variety: 'Potentate'; House D1)

The object and treatments in this experiment, conducted in co-operation with the Virology Department, are described on page 51 of this Report. Samples of good quality fruit were obtained from each of the six experimental treatments on nine occasions between May and August for analysis of the expressed sap.

It was found that neither soil sterilisation nor the foliar sprays had any significant effect on the titratable acidity, reducing sugar content, total solids content or refractive index of the expressed juices; the composition of the saleable fruit was satisfactory throughout the trial. As noted in an earlier section of this Report, little difference in growth was observed between the steamed and unsteamed treatments, the soil in this house having been steamed regularly in preceding seasons. Further studies on the effect of steaming on fruit composition are planned for 1962, using fruit from the soil sterilisation experiment conducted by the Crop Protection Department.

The effect of sprays containing urea on the composition of fruit from healthy and virus-infected tomato plants (variety: 'Moneymaker'; House D2)

Studies of the effect of virus infection of the plant on the composition of the fruit were described in the Annual Report for 1960. During 1961 further fruit samples were analysed from an experiment conducted in co-operation with the Virology Department; details of the treatments are given on page 52 of this Report. Two strains of virus, mild and severe, were used to infect the plants.

Sprays containing urea had no effect on any aspect of fruit composition studied. Reducing sugars and total solids in the expressed sap were, however, significantly increased by virus infection, as shown by the following mean values:—

	Uninfected	*Infected (mild strain)*	*Infected (severe strain)*	*L.S.D.**
Sugar in the expressed sap (*g./100 ml.*)	2·71	2·80	2·97	0·14
Total solids (*g./100 ml.*)	4·20	4·33	4·43	0·12
Titratable acidity (*milliequivalents per 100 ml.*)	7·22	7·26	7·05	–

* Least significant difference at $P = 0{\cdot}05$

These results confirm those observed in 1960; the content of sugars and total solids is increased by virus infection, accompanied by some loss in yield.

The mean sugar content of the fruit rose progressively from May to mid-August, confirming the trend generally found in the course of these investigations of fruit composition.

Studies of the non-volatile acids of the tomato fruit (J. N. Davies)

Studies of the non-volatile acids of the tomato fruit were continued during 1961, using the technique of gradient elution chromatography on anion exchange resins Further data on the quantitative changes in the individual acids during ripening have been obtained, confirming and extending the limited results of 1960. In addition to this work on the changes during the normal development of the tomato fruit, a study of the acid composition of normal and "blotchy" fruit tissue has begun.

Considerable attention has also been given to a preliminary investigation of the effect of various nutritional factors on the individual acids of the tomato fruit The long-term factorial nutritional trial with tomatoes in Block B has proved a useful source of experimental material for this work. Eight plots from the trial were selected for the initial study, forming a 2^3 factorial combination of two levels each of nitrogen, phosphorus and potassium. All the plots were unlimed and received applications of magnesium sulphate. Samples of the best quality fruit available from these plots, collected in July, 1960 and again in July, 1961, were preserved in ethanol for analysis of the organic acids.

The concentrations of malic and citric acids, and of the amino acids glutamic and aspartic, were higher in the 1961 samples than in those of 1960, especially at the low potash level (K1). The symptoms of potassium deficiency were also less marked during 1961, the K1 plots receiving potassic fertiliser for the first time. Similar trends in the data were observed in both years, however, and the two sets of results were combined for statistical analysis. The effect of high as compared with low potash was to increase the mean values for malic and citric acid concentrations, the difference being significant at $P = 0{\cdot}001$ in each case. The concentration of malic acid was significantly lower at the low nitrogen (N1) level than at the high (N3) level. A similar trend, though not statistically significant, was shown by citric acid. A significant interaction was found between the effects of nitrogen and potash on the concentration of citric acid in the fruit, the mean values, expressed in micro-equlivalents/10 g. fresh tissue, being as follows:—

Nitrogen levels	*Potash levels*		*Nitrogen level means*
	K1	*K3*	
N1	278	474	376
N3	251	604	428
Potash level means	265	539	

The results show that, at the low level of potash (K1), the higher application of nitrogen slightly decreased the concentration of citric acid, whereas at the higher potash level (K3) there was a marked increase with increasing nitrogen levels. Similar trends were in general observed for malic acid, although the results just failed to attain statistical significance at $P = 0{\cdot}05$ (variance ratio test: required 5·32, found 5·19). Phosphate had no significant effect on the concentrations of malic and citric acids in the fruit.

The concentrations of the nitrogen-containing acids glutamic, aspartic and pyrrolidonecarboxylic (PCA) in the ethanol extracts of tomato fruit were all markedly influenced by the

nitrogen levels in the soil. Higher concentrations of these acids were found at the high nitrogen level (N3) than at the low level (N1), the differences being significant at $P=0{\cdot}001$ in each case. The concentrations of aspartic acid and PCA were significantly higher at the low potash level (K1), but glutamic acid was unaffected by the level of this nutrient. Inadequate phosphate levels also resulted in a significant increase in the nitrogen-containing acids.

Pectic enzymes in tomato fruit (G. E. Hobson)

The effects of potassium and nitrogen deficiences on pectin methylesterase activity have been studied in fruit from the main factorial nutritional trial in Block B (see page 50). The activity of this enzyme was about 40% lower in fruit from plants grown at the low level of potash (K1) as compared with those receiving an adequate level of this nutrient (K3). Studies of pectin methylesterase have now been completed, and the results have been prepared for publication.

A further pectic enzyme, polygalacturonase, has been the main subject of investigation during the year. Careful attention has been given to the methods available for the extraction and estimation of this enzyme in plant tissue, and a modified procedure for its determination in fruits has been evolved.

This modified method has been applied to the study of changes in polygalacturonase activity during ripening of the fruit of two varieties of tomato ('Potentate' and 'Immuna'), the fruit being examined at five stages of ripeness as in the earlier work on pectin methylesterase activity. Both whole fruit and outer locule walls have been studied.

In contrast to the relatively small increase in pectin methylesterase activity during ripening, the activity of polygalacturonase, though not detectable in mature green fruit, showed an extremely rapid rise thereafter. Using the mean data previously obtained for the time taken to ripen between comparable successive stages of pigmentation, the activity of the enzyme is seen to increase exponentially with time from the green-orange to the orange stages, with a further significant increase to the red condition. Polygalacturonase activity in the red fruit was almost 200 times higher than in fruit just beginning to turn colour (green-orange). In the early stages of ripening the enzyme became detectable in samples of whole fruit before it could be found in the comparable locular walls, thus suggesting that the activity first appears in the locular contents.

Polygalacturonase activity has also been studied in "blotchy" tomatoes. Highly significant differences were found between the red and green areas of such fruit, the activity being far higher in the red areas.

Further investigations in progress on polygalacturonase include the relation between *p*H and activity, the stability of the enzyme and its distribution within the cell.

Subsidiary studies on the ripening of tomato fruits injected with various enzyme inhibitors have been continued. In the course of these studies an interesting demonstration of the complexity of the vascular system of the tomato plant resulted. Thus sodium arsenate, injected into a fruit, spread along the vascular strands into the main stem, killing adjacent tissues. It was seen that certain leaves, or parts of leaves, were closely associated with certain trusses; the affected leaves were not necessarily those nearest to the truss concerned.

4. STATISTICS

by

D. COOKE

The appointment of J. H. Gisborne during the year has enabled the Section to give prompter and fuller assistance to workers at the Institute and at the Experimental Horticulture Stations of the N.A.A.S. Many queries on experimental design and statistical analysis of data have been answered, and statistical reports have been provided on data received from the N.A.A.S.

The Institute is making greater use of the electronic computer at Rothamsted Experimental Station and, in 1961, data from about thirty Littlehampton experiments were analysed by it; some of the N.A.A.S. data received were also analysed on the computer. As more data are being analysed by electronic computer it would be a great advantage to record them in a form, such as on punched paper tape or cards, which is immediately acceptable by the computer. At present data to be analysed by electronic computer are punched on paper tape from written records, usually after preliminary computation with a desk machine. Trials using a paper tape punch to record tomato yield data have been promising and are to be continued in 1962.

Experimental technique with mushrooms (D. Cooke and P. B. Flegg)

The series of experiments on this subject, carried out over the last three years in co-operation with P. B. Flegg of the Horticulture Department, was finished towards the end of the year. A summary of the work is being prepared. Only work done in 1961 is reported here.

Experiments on spawn rate showed that it affected yield. The results are of practical interest for growers and are therefore presented in a special research report (see page 118); they also suggest that the improvement in uniformity which results from using equal weights of spawn for each tray is not large but is none the less worth the extra trouble of weighing out the spawn. The effect of possible differences between cartons of spawn on variability was also investigated but no effect was found.

Computing templates (J. H. Gisborne)

Simple cardboard templates were developed for the extraction of block-totals and main-effect and interaction totals in the commonly used 3^3 layout confounded in blocks of nine plots. A convenient cyclostyled pro-forma table giving the two-way tables and main effect marginal totals, the standard errors and significant differences was also introduced and could be used both during calculation and for the final presentation of results. This effected considerable saving of time. A fuller description of the work has been accepted for publication elsewhere (*Trop. Agriculture, Trin.*, **39**, 2, 1962, 141–5).

Work for outside bodies (D. Cooke and J. H. Gisborne)

D. Cooke continued to serve on the Bulbs, Flowers and Glasshouse Working Parties of the Agricultural Improvement Council's Experimental Horticulture Committee. Data from forty-one experiments, carried out at Experimental Horticulture Stations, have been analysed involving 1,487 plots and an average of 5·2 variates per plot.

5. ENTOMOLOGY

by

N. W. HUSSEY

Mushroom Phorids (N. W. Hussey and Barbara Gurney)

Megaselia halterata (Wood), the "Worthing Phorid", was unusually abundant on commercial holdings in south-east England during the summer and so, with the co-operation of local growers, work on practical control methods was intensified.

Although a promising technique of laboratory culture was developed later in the year, insufficient adult flies were available for controlled experiments. Most observations were therefore made on commercial farms, either by exposing small volumes of spawned compost in heavily infested houses or by sampling compost in treated trays placed near the doors to be specially vulnerable to Phorid attack.

Aldrin, diazinon, malathion and synergised pyrethrins incorporated into compost, at rates of 10 p.p.m. and 50 p.p.m., before spawning, were tested as potential Phorid controls. Only diazinon had any effect on the numbers of pupae subsequently found in treated compost; although the number of eggs laid was unaffected, control of the larvae was virtually complete, even at the lower rate. When incorporated in the casing at 10 p.p.m. none of these insecticides reduced the pupal populations in the compost, but diazinon produced a more flocculent mycelial growth in the casing compared with that of the untreated controls.

At one local farm Phorids caused almost complete failure in several successive crops. Diazinon, as an emulsion, was mixed into the compost at 10 p.p.m. during machine-spawning of five subsequent crops. The first crop had over 200 larvae per handful of compost ($\equiv$30g. sample) at the time of treatment and these were eliminated within four days. The remaining crops were infested by few larvae despite the many flies still in the farm. Yield from all the treated crops was satisfactory, the grower reporting an average of over 1 lb./sq.ft. in the first flush.

As a further check on the phytotoxicity of diazinon to mushrooms a cropping experiment was done at the Institute. Yields were compared from beds where the insecticide was incorporated at 10 and 50 p.p.m. in the compost, before and after peak heating, or in the casing. The yield (2·0 lb./sq.ft. in six weeks) was unaffected by the treatment, but diazinon at 50 p.p.m. in the casing delayed the appearance of the flushes by three days. Through the kindness of Dr. E. D. Chilwell of Fisons Ltd., mushrooms grown on compost treated at both concentrations after peak heating were analysed but no diazinon residue could be demonstrated. The incorporation of diazinon in compost at 10 p.p.m. during spawning is therefore sufficiently safe to justify large-scale trials under commercial conditions.

Earlier work showed that diazinon partly breaks down during the peak heating process, so that on those commercial farms which have no facilities for machine-spawning higher rates of the insecticide would have to be incorporated in the compost at filling. It will therefore be necessary to determine whether biologically active residues can survive if these higher rates are used.

Surface applications of synergised pyrethrins to newly-spawned compost reduced the number of eggs laid, and phytotoxicity trials showed that rates up to 0·005 g. actual pyrethrins per sq.ft. were safe. Experiments were also done on the use of pyrethrins continuously liberated into the atmosphere of spawn-running rooms by electrically-controlled aerosols. This work is to be extended as soon as circumstances permit.

Studies on the ecology of adult *M. halterata* confirmed that almost all the infestation of a compost occurs within three weeks of spawning. If spawn-running takes place within a fly-proof structure, oviposition after casing is usually insufficient to produce larval populations above 100/30 g., which are regarded as potentially capable of affecting yield. Occasionally, however, crops were seriously infested during the first week after casing and it is believed that the degree of mycelial growth within the compost at casing was the critical factor. Pot experiments clearly demonstrated that eggs were only laid where active mycelial growth was available. Preliminary trials have been made on the practical possibilities of ensuring rapid colonization of the compost by "through spawning" at higher than average rates.

Mushroom Cecids (I. J. Wyatt)

The use of aldrin incorporated in the casing at 10 p.p.m., while effective for the control of *Mycophila* larvae, has not proved satisfactory against *Heteropeza pygmaea*, and trials were done to develop a more suitable method.

Vantok was incorporated in the casing with aldrin in an attempt to reduce the bacterial infection of sporophores normally associated with *Heteropeza* infestation. Although the trial showed that these substances could be admixed at the recommended rates without affecting yield, bacterial contamination was not reduced.

Losses due to damage by *Heteropeza* and bacteria could be decreased by restricting the frequency of watering, but this was uneconomic, as sporophore production was inhibited by dry conditions. Aldrin incorporated in the composts at rates of 10 and 50 p.p.m. was also ineffective.

The most promising technique was to mix Y–BHC or aldrin in the casing at 50 p.p.m. Aldrin at this relatively high rate is probably undesirable, owing to the risk of toxic residues. but Y–BHC seems worth further investigation. There were no phytotoxic effects from Y–BHC at 50 p.p.m., but at 100 p.p.m. flushes were delayed and some loss of crop occurred. Owing to the wandering of larvae from plot to plot, the conduct and interpretation of replicated experiments was difficult. However, until large-scale movement occurred after about five weeks' cropping the treatment of the casing with 50 p.p.m. Y–BHC reduced the proportion of infested sporophores from 80% to less than 10%.

Studies on the developmental morphology of mushroom-infesting Cecidomyiidae have continued and it has been demonstrated that the paedogenetic phase in the life-cycle of *Heteropeza* is a pharate pupa.

Specimens of Cecidomyiidae from all parts of the world were determined for the Commonwealth Institute of Entomology.

Trials on the use of methyl-bromide as a substitute for the "cook-out" procedure in mushroom houses (N. W. Hussey, I. J. Wyatt and J. J. Hesling)

Although "cooking-out" is an invaluable hygienic procedure on commercial farms, temperatures of 160°F., or above, considerably affect house structures. With the co-operation of Dr. A. B. P. Page and Mr. O. Labatti of Imperial College, preliminary studies were made on the use of methyl-bromide as a more suitable sterilising technique. Preliminary tests on eelworms and Cecid larvae showed that a concentration/time product of 250 oz./hr. per 1000 cu.ft. was necessary to ensure complete kill. One of the cropping houses (capacity 4000 cu.ft.) at the Institute was fumigated at this C.T.P. for 6 hr. using 31 lb. of fumigant at a cost of £11 10s. The treatment eliminated mites and insects, and the eelworm *Aphelenchoides composticola* where

this was active in the compost or in moist situations in the structure. However, not all *Ditylenchus myceliophagus* and dry *A. composticola* were killed, and it was concluded that a C.T. product of 600 oz./hr. in an overnight fumigation would be necessary. Longer fumigation would reduce the cost proportionately, and with bulk purchase of fumigant the outlay would be further reduced. Methyl-bromide does not affect fungal competitors and pathogens and it is proposed to investigate mixtures of ethylene oxide and methyl-bromide.

Agromyzid Leaf-miners (Barbara Gurney)

The two strains of *Phytomyza atricornis* Mg. reported last year were used for studies on host preference to test the hypothesis that this polyphagous species comprises strains with different, but overlapping, host ranges. It was necessary to devise a suitable standard for categorising host preference, as the presence of a mine does not necessarily reflect free choice by the ovipositing adult. The ratio between the number of female feeding punctures and the number of eggs laid (F:E ratio) was tested as an index of host suitability. Theoretically, the lower the ratio, the more suitable the host. Female flies were liberated in large cages enclosing 18 lettuce plants, replicated for differences in nutrition. The lowest ratios were found on those plants with the highest nutrient level. Similar results were obtained when flies were offered plants growing under different light intensities.

The F:E ratios on several chrysanthemum varieties reflected the density of larval mines subsequently found, i.e., low ratios gave high larval densities. This ratio provides a useful standard for comparison of host preference, and will be used to compare the host ranges of other field strains.

The survey of Agromyzidae on ornamental plants continued but few mines were found on any hosts, presumably because of much parasitism in the spring.

Glasshouse Red Spider Mite (N. W. Hussey and W. J. Parr)

The effect of different degrees of mite damage on cucumbers was studied by controlling populations on test plants for different periods. Five treatments were replicated four times on plots of three plants, managed in the normal commercial fashion. Mite populations were assessed every three weeks, using leaf damage indices which had been related to mite populations in an earlier trial. Leaf damage was assessed at five heights and about 50 leaves were examined on each plot.

In a subsequent experiment (see page 95) it was shown that the interval between leaf damage and crop reduction was about five weeks.

The dates on which yield increments of mite-infested plants fell below those of plants maintained free from damage were calculated. Decreases were caused by mite populations five weeks earlier when the populations must have been critical. Similar critical populations were calculated from the different treatments. It was concluded that cucumbers can tolerate considerable mite populations without loss of yield. In the coming season it is intended to test the effect of different degrees of leaf-damage on yield by spraying only when the damage reaches given levels. The fewer sprays required by programmes timed in this manner would limit the speed of selection of resistant mites to any new acaricide.

Studies on the factors initiating diapause were continued. Numerous observations were made to clarify the present confusion regarding the particular instar which is stimulated by diapause-inducing conditions (i.e., short daylength, low temperatures and plant condition). Diapausing females were obtained only when both the proto- and deutonymphs were exposed

to these conditions. Contrary to Continental experience, however, few female mites of all U.K. strains tested entered diapause under artificial conditions. It is possible that, even on outdoor plants, mites are less ready to diapause in the generally mild conditions along the south coast.

The dissemination of mites from heavily infested plants was studied by placing migratory "ropes" at the centre of concentric rings of tomato seedlings and the mite movements were recorded by the subsequent infestation of the seedlings. The results confirmed the positively phototropic behaviour found in individual female mites.

The predatory mite *Phytosieulus reigeli* was received through the kindness of Dr. L. Bravenboer (of Naaldwijk), and preliminary studies made on its development and food requirements. This mite shows promise of being a most efficient predator in glasshouses.

6. NEMATOLOGY

by

J. J. HESLING

Having begun with an almost empty laboratory the past year has seen the collection of equipment and construction of special apparatus for nematological work and the build-up of a moderate library of essential books. Work has followed two lines; firstly, investigations on eelworms associated with mushroom growing and, secondly, a study of the narcissus race of the stem and bulb eelworm *Ditylenchus dipsaci*. The line of work on the narcissus eelworm indicated in the 1960 Annual Report (an investigation of the efficiency of hot-water treatment of bulbs to control eelworm) was changed during the year, at the request of the A.R.C., to a general study of the biology of the eelworm.

Mushroom eelworms

Eelworms abound in the raw material of compost stacks. Most manure stacks contain forms belonging to several genera, species of *Pelodera*, *Rhabditis*, *Mesorhabditis*, *Panagrolaimus* and *Diplogaster* being commonly found. Synthetic composts (made from straw plus proprietary additives) often contain less varied populations, with *Panagrolaimus* and *Cephalobus* as common genera, but rarer eelworms, e.g., *Bunonema*, may be encountered in large numbers. These eelworms are saprophagous or predatory; fungal-feeding species have not been found in composts examined.

The heat in the centre of a "working" stack (*ca.* 160–170°F.) kills the eelworms, but many eelworms survive on the cooler outside of the stack. Flies and mites which inhabit the stacks carry eelworm larvae on their legs and bodies, and 94% of a sample of *Sphaerocerid* flies from one manure stack carried eelworms, with an average of ten eelworms per fly. Fortunately, it is unusual for this type of fly to enter cropping houses.

The peak-heating process, efficiently done, kills all eelworms. Eelworms may subsequently be introduced into the beds in unsterilised casing material. Eelworms found in peat from several sources included fungivorous species of *Tylenchus* and *Aphelenchoides*, and the saprophagous *Panagrolaimus*. Eelworms in peat may be few, but experiments have shown that they can multiply rapidly and the sterilisation of all casing material is recommended.

Comparison of the pathogenicity of a saprophagous and a fungivorous species of eelworm

Pelodera cylindrica (Cobb, 1898), Dougherty, 1953—a saprophage—and *Aphelenchoides composticola* Franklin, 1957 were added to jars of spawned manure compost. Mycelium began to deteriorate after six weeks in jars infested with *Aphelenchoides*, whereas mycelium infested with *Pelodera* remained healthy. The population of *Aphelenchoides* increased from ten individuals to 1½ millions in seven to eight weeks; at this time the eelworms swarmed on the sides and lids of the jars, and were readily carried by mites. The population of *Pelodera* increased tenthousand-fold in two weeks but then fell slowly to undetectable levels. Eelworms may secrete substances harmful to mushroom growth, but measuring the *p*H of infested composts revealed no effects by the eelworms. It was noticed, however, that the *p*H of jars contaminated with *Chaetomium* was consistently high, suggesting an explanation of the antagonism of *Chaetomium* to mushroom, which does not thrive in a *p*H higher than 8.

Persistence of Aphelenchoides composticola

Active *A. composticola* can withstand starvation for at least ten weeks, and some specimens may survive at least six weeks' drying. Both starved or rewetted *Aphelenchoides* can attack mushroom mycelium and reproduce. This ability to persist in adverse conditions suggests that this eelworm may be carried in water or even blown on dry compost or casing material.

Narcissus race of Ditylenchus dipsaci

Bioassay techniques

To develop a technique for the bioassay of hot-water treated eelworms, a study was made of the natural invasion of onion seedlings grown in infested soil and the subsequent development of the eelworms in them. An average of only 15% of the eelworms entered the seedlings and variability was high. Attempts to reduce variability by placing known numbers of eelworms on seedlings were unsuccessful and, finally, eelworms were inoculated into the tissues. By this method all the seedlings were infected and an average of 80% of the eelworms could subsequently be found in the onion tissue, variability being low. Eelworms quickly left the inoculation site and migrated through the tissues; eelworm movement tended to be towards the root/shoot junction and was more rapid in this direction. Egg laying was observed six days after inoculation.

Invasion of narcissus bulbs in eelworm-infested soil

Eelworms were found in bulbs (variety 'Magnificence') one week after planting in soil with an infestation of ten eelworms per gram of soil. Eelworms remained few until green leaves appeared through the nose of the bulb, when there was a ten-fold increase with a subsequent steady rise.

In spite of almost 100% infection of the bulbs, definite symptoms were seen on two bulbs only out of 90 bulbs examined.

Effect of different eelworm inocula on narcissus bulbs

Different numbers of eelworms were inoculated into or close to the neck of narcissus bulbs (variety 'Magnificence') planted in late August, 1961. The inocula ranged from four to 3,200 eelworms per bulb. In the first 14 weeks of growth the inoculum level had no marked effect on the emergence of leaves through the soil or on the severity, incidence or earliness of symptoms. Many plants were symptomless. The course of the disease will be followed.

D. dipsaci in the field

In July, 1961, 20 foliage samples were collected from two infested fields. On one field two small patches of diseased bulbs had been rogued out by the grower, but more eelworms were recovered from foliage from this field than from the unrogued one. Further work on the effectiveness of roguing as a partial control measure is needed, particularly as bulbs may be infested but show no symptoms. The movement of eelworms from diseased plants, and the fluctuations in the soil population, need close study and for this purpose a small plot has been planted with infested bulbs.

7. MYCOLOGY

by

F. T. LAST

Mr. P. H. Williams retired on 30 September and was succeeded in December by Dr. F. T. Last.

Verticillium Wilt

Tomato (P. H. Williams)

In experiments done to test the effects of growing conditions on disease symptoms, shading affected those caused by *V. albo-atrum* but not by *V. dahliae*. Shading, when coupled with night temperatures of 50–60°F., decreased symptoms caused by *V. albo-atrum* but at higher temperatures, *c* 70°F., shading increased them.

Carnation (Marion H. Ebben)

Experiments measuring the persistence of inoculum of *Verticillium cinerescens*, cultured on vermiculite and buried in soil, have been stopped because most of the uninoculated control plots became contaminated. Data were obtained suggesting that *V. cinerescens* can survive for at least two years in soil planted with non-susceptible crops, e.g., tomato and carnation. Infectivity, however, seemed to decrease rapidly in the absence of a susceptible host. After removing infected plants six months before replanting, subsequent spread was slower than after immediate replanting. Although *V. cinerescens* was readily isolated from stems it was never found on, and rarely in, roots of infected plants.

Petal Blight of chrysanthemum caused by Itersonilia perplexans (Doreen G. Gandy)

(a) *Infection conditions.* Several factors were tested in preliminary experiments. To infect, spores seem to need free moisture and temperatures below 26–28°C. At higher temperatures the fungus is killed.

More inoculations were successful, and lesions appeared sooner, on old than on young flowers. This age effect was mimicked by bruising florets. Bruising increased the mean proportion of successful inoculations from 16 to 40%.

(b) *Host range. I. perplexans* was isolated, using the spore-fall method (Derx, 1930), from foliage of several hosts collected in W. Norfolk including *Galinsoga parviflora, Sonchus oleraceus, Anthemis* sp., *Senecio vulgaris* and *Veronica* sp. Inoculation experiments showed that (i) isolates of *I. perplexans* from dahlia and helianthus infect chrysanthemum and (ii) a chrysanthemum isolate developed on flowers of *Taraxacum officinale, Matricaria inodora, Bellis perennis, Anthemis cotula, Achillea* sp., *Inula* sp., *C.maximum* 'Esther Read', aster 'King George V', dahlia, pyrethrum and sunflower. Disease was less severe on these hosts than on the chrysanthemum 'Penrod', which was more susceptible than the variety 'Sweetheart' and its various colour forms.

Unknown disease of orchids (P. H. Williams)

A species of *Gloeosporium* isolated from necrotic lesions on leaves and pseudobulbs of orchids, including *Oncidium* and *Phalaenopsis*, caused similar lesions when re-inoculated to *Phalaenopsis*.

Cultivated mushroom (Doreen G. Gandy)

"Watery Stipe" disease

Because it has been suggested that a virus may be the cause of this disease—there is no evidence indicating that bacteria and fungi are responsible—experiments were done with M. Hollings (Virology) to test this hypothesis. The work is described in a special report on page 103.

Cropping experiments

The series of experiments testing the effects of temperature, relative humidity and ventilation rate were continued with P. B. Flegg (see Horticulture Department report, page 89). Appreciable numbers of sporophores developed waterlogged tissues at 65°F. and RH.80–95%, regardless of the ventilation rate. These symptoms were probably caused by an adverse environment and not by an infectious agent.

REFERENCE

DERX, H. G. (1930). Étude sur les Sporobolomycètes. *Ann. mycol., Berl.*, **28,** 1–23.

8. VIROLOGY

by

M. HOLLINGS

The year's work has continued the analysis of the virus complex in carnation and the development of techniques for producing virus-free clones, the study of the epidemiology of tomato mosaic, and the efforts to purify and improve the diagnostic test for chrysanthemum stunt virus. Progress has been made in all but the last of these. Construction of the research glasshouse block has begun and, when completed, its facilities will enable more work with chrysanthemums to be resumed, and work on bulb and shrub viruses to be expanded.

Carnation viruses (M. Hollings, Olwen M. Stone and Margaret E. Norrish)

Attention has been concentrated on carnations, not only because many virus problems exist in them, but also because they provide a better system than most other ornamental plants for developing techniques of general application.

Carnation mottle

In further host range studies, mottle virus infected 32 out of 110 plant species; symptomless infection occurred in 17 species of which nine were invaded systemically. Fifteen species developed symptoms. *Chenopodium amaranticolor* remains the best indicator and assay host, regularly detecting the virus in sap diluted 1/40,000 and occasionally, 1/200,000. Systemic chlorotic flecks sometimes occurred, particularly in plants initiating flower buds; but this systemic invasion was confined to a few leaves immediately above those inoculated, and further inoculations from them gave no more systemic infections than did other inocula. Both the purple and yellow leaved varieties of *Atriplex hortensis* supported mottle virus systemically and in high concentration, and were very satisfactory as source plants for purification of the virus. None of the four species of *Dianthus* tested (*D. barbatus*, *D. chinensis*, *D. superbus* and *D. caryophyllus*) was satisfactory as an indicator plant, though carnation was a good source for virus purification. *Saponaria officinalis* and *Lychnis chalcedonica* were not infected by sap inoculation with mottle virus, but were when inarch grafted with infected scions of carnation.

A strain of mottle, designated PSR, isolated from carnation variety 'Pink Shibuiya', differed from all other isolates in reactions in several plants; it was very closely related serologically to the typical strains of mottle, and the latter protected *Atriplex* plants against infection with it. Purified preparations of PSR and typical mottle viruses gave identical light-scattering zones when centrifuged in density gradient columns of sucrose, and the reaction line of mottle virus in gel-diffusion slides was continuous with that of the PSR isolate.

Carnation ringspot

The work on mottle virus being nearly complete, similar studies are now being done on ringspot. Ringspot virus infected 56 out of 82 plants tested, but although it has a much wider host range than mottle, preliminary results suggest that it spreads less readily in carnation. When uninfected 'Joker' carnation cuttings were handled, before rooting, alternately with cuttings infected with ringspot, only five out of 82 cuttings became infected.

Carnation ringspot virus gave a sharply defined zone at the 24% sucrose level when centrifuged in density gradient columns of sucrose. Although all the serological activity and most of

the infectivity was contained in the visible zone, some infectivity was detected in samples from below, but never from above, this zone. Accurate removal of samples from the different levels is important in trying to separate different fractions, or mixtures of viruses, and different methods have been compared.

Carnation plants can readily be freed from ringspot virus by heat treatment alone, or by rooting tips of approximately 0·5 mm. length in sterile tube culture: ringspot need present little difficulty in well-run commercial stocks.

Carnation latent

Latent virus was successfully purified and concentrated by the butanol-centrifugation method and antiserum with a titre of 1/5,000 obtained by two intramuscular injections into rabbits of such preparations emulsified with Freund's adjuvant.

Purified preparations of latent virus produced a characteristic, broad zone in density gradient centrifugation columns. Further host range tests have failed to find a test plant that shows any symptoms when infected with this virus.

Carnation vein mottle

Preliminary attempts to purify this virus from *D. barbatus* by the butanol-centrifugation method resulted in a loss of most of the infectivity; a faint broad zone, believed to be specific for this virus, was produced in sucrose density gradient columns.

Carnation etched ring

Cuttings from commercial carnation varieties, already containing mottle, which were infected with carnation etched ring during 1960 were grown during 1961 to follow the sequence of development of symptoms up to the time of flowering. No symptoms were seen until four months after the cuttings were taken, about six weeks after the first stop. Chlorotic rings were soon followed by necrotic rings and flecks and, in the variety 'Joker', by necrotic blotches. Thereafter, the symptoms varied in intensity but always remained visible until flowering when necrotic stem streaking was observed. Stem streaking began after eight months, just before the first flowers opened; it occurred on the main and axillary flower stems, but never on vegetative stems and we have found no other carnation virus that gives this symptom. Flower size and quality were variable; and control plants, infected only with mottle virus, showed similar symptoms of colour breaking, distortion and proliferation of the petals. Similarly, speckling of the leaf tips, small pimple enations on the stems and leaves, and basal splitting of the stems were non-specific. Small necrotic rings on the leaves, not seen in virus-free seedlings, were also found, though less frequently, in carnations infected with other viruses. In the commercial varieties 'Joker', 'Improved William Sim', 'Sparkes' Sim' and 'Tangerine Sim' there was no loss of vigour compared with the control plants with mottle only, but Chabaud seedlings, originally free from virus, were noticeably smaller after infection. It is not known if this was due to etched ring or to the complex of viruses transmitted by the orginial graft.

The absence of symptoms in the young cutting stages is important because roguing is normally done then. To eliminate etched ring, roguing must be delayed until the plants are well grown.

In transmission experiments, one out of 80 plants of 'Joker' was infected after mechanical inoculation either with sap from leaves ground in a mortar with phosphate buffer, or from cut edges of leaves from infected plants.

Inarch grafts, stem slivers inserted into the stems of test plants and abraded leaf patches inserted under the epidermis of stems, all caused infections, and symptoms developed in three to eleven weeks.

Aphid transfers using a carnation aphid now regarded as *Myzus persicae* (Sulz.) f. *dianthi* caused infection in one out of 24 plants after a short acquisition feed (2–5 min.) and one out of 20 plants after an acquisition feed of seven days. Hitherto all isolates of etched ring virus have also contained carnation mottle, but as mottle virus is not transmitted by aphids it is hoped to obtain etched ring virus alone, to purify it and to study its economic effects.

Two plants obtained by tip culture from carnations containing etched ring and mottle viruses now appear to contain etched ring only. These plants were symptomless for more than a year after the tips were rooted, but typical symptoms of etched ring appeared after they were first stopped.

Last year we had no conclusive evidence that this was a virus disease; transmission by both aphids and mechanical inoculation definitely establishes this.

Carnation streak

Although the circumstantial evidence from work in the U.S.A. suggests that this is a virus disease, definite proof is still lacking, for the disease has been experimentally transmitted only by grafting and between carnations; neither specific particles nor serological activity has been found. Symptoms similar to those described by American workers, and seen in the U.S.A. by M. Hollings, have been found on commercial holdings in this country. The symptoms appear, according to variety, as white, yellowish-brown or purplish broken lines or streaks on the leaves, usually parallel to the veins. Such symptoms were induced in plants of Sim varieties by inarch and stem sliver grafts from affected carnations.

A strain of pelargonium leaf curl virus in carnation

A virus isolated by sap inoculation to *Chenopodium amaranticolor* and *Gomphrena globosa* from carnation varieties 'Dusty' (grown in Italy) and 'Orchid Beauty' (grown in the United States), differed from any previously obtained from carnation. This virus (designated CIRV) was assayed in *C. amaranticolor*, which reacted with tiny necrotic local lesions in 3–6 days, followed by systemic semi-necrotic flecks and spots, with leaf buckling. *Nicotiana clevelandii* proved satisfactory for culturing the virus; local chlorotic and semi-necrotic spots in 2–6 days were followed after a further 1–2 weeks by severe systemic crinkle-mottle, necrotic speckling and dwarfing. Although this virus readily infected 45 out of 84 plant species by mechanical inoculation we have so far been unable to infect healthy carnation seedlings.

The virus was quite stable *in vitro* and could be purified in several ways; the butanol-centrifugation method proved best. Preparations from diseased, but not from healthy, plants contained "spherical" particles about 28 mμ diameter in electron micrograms kindly made by Mr. H. L. Nixon at Rothamsted. The *in vitro* properties in *N. clevelandii* sap were: maximum infective dilution more than 1/50,000, infectivity abolished after 10 min. at 80–85°C., and sap stored at room temperature lost more than 97% infectivity after five weeks, whereas at 0°C. little or no loss occurred during this time.

Intramuscular injection of purified preparations into rabbits gave a highly specific anti-serum with a titre of 1/1024 against the homologous antigen in precipitin tube tests, but no reaction with control preparations from healthy plants. A serological reaction could be detected in purified preparations diluted 1/50,000, but clarified sap from infected *N. clevelandii* had a titre of only 1/20.

Centrifugation in sucrose density gradient columns gave characteristic zones in which infectivity and antigenicity were concentrated. The virus reacted with antiserum to pelargonium leaf curl virus, as did PLCV with antiserum to the carnation virus.

Relationships of pelargonium leaf curl virus (PLCV)

Further study of PLCV has shown relationships and similarities to several other viruses; PLCV and CIRV each reacted almost to titre with antiserum to the other. PLCV also reacted with antiserum to Rothamsted tomato bushy stunt virus in a test done by Mr. A. J. Gibbs at Rothamsted; we repeated this with antiserum prepared against our own isolate of tomato bushy stunt (TBSV) and found that, although PLCV and TBSV reacted mutually, TBSV did not react with CIRV antiserum, nor CIRV with TBSV antiserum. Comparative host range tests showed many similarities between these viruses, and their properties *in vitro* were closely similar. Because pelargonium leaf curl was described before bushy stunt, priority demands that it should be known as the tomato bushy stunt strain of PLCV. PLCV and CIRV caused only local infection in *Lycopersicon esculentum*, whereas TBSV invaded it systemically, inducing the "bushy stunt" disease which gave the virus its name. However, symptoms indistinguishable from typical leaf curl were produced by CIRV and TBSV in *Pelargonium*.

All these three viruses had similiar icosahedral particles, about 28 mμ in diameter, in electron micrograms; all produced similar zones in density gradient centrifugation, including the characteristic formation of multiple zones which is discussed separately.

Some other viruses, carnation ringspot, turnip crinkle, and a virus from white clover, though similar in host range and many *in vitro* properties, were not serologically related to this group of viruses.

The study of relationships between these viruses continues, particularly in relation to the natural sources of each.

Chrysanthemum viruses (M. Hollings)

Attempts have continued to purify stunt virus, so that a rapid serological test might be developed. We have also sought a better indicator plant for detection of stunt than chrysanthemum variety 'Mistletoe'. Indexing by grafting to this variety takes a minimum of two months before symptoms are visible, and often 4–6 months elapse before the indicator plant shows symptoms. In one instance infection first showed 14 months after grafting. Workers in the U.S.A. have used the variety 'Blanche' as an indicator, for it reacts more quickly under their conditions. This variety, apparently wholly infected with a leaf-mottling virus, develops symptoms of veinal flecks on the younger leaves 6–10 weeks after infection with stunt. These symptoms are of the kind caused by leaf mottling viruses, and may be an intensification of the symptoms of the intrinsic virus in 'Blanche' rather than a specific reaction to stunt. We have found this variety unreliable and very inferior to 'Mistletoe' under our conditions. Inoculations or inarch grafts with chrysanthemum stunt to 54 species induced symptoms in only two of them; *Chrysanthemum parthenium* was stunted, the leaves smaller than normal and very yellow; the flowers opened up to 14 days earlier than in uninfected plants and were much smaller.

All efforts to purify stunt virus have failed, and no specific light-scattering zones have been consistently detected in density gradient centrifugation of such preparations. Because there is no quantitative assay host it is not possible to find at what stage in purification infectivity is lost, but many preparations by the butanol-centrifugation method caused no infection when inoculated to 'Mistletoe' chrysanthemums, and contained no particles in electron micrograms.

Aspermy virus could be purified and concentrated from young chrysanthemum leaves; such preparations were highly infective, gave a characteristic zone in density gradient centrifugation, and were serologically active. Aspermy virus is much less stable than stunt and, from dilution tests, present in lower concentration in the chrysanthemum. It is therefore surprising that aspermy virus could readily be purified from chrysanthemum, whereas stunt could not.

Dahlia mosaic (M. Hollings and Olwen M. Stone)

Using several dahlia varieties showing typical symptoms of dahlia mosaic, we have been unable to confirm the claim of French workers to purify the virus and obtain a specific antiserum by injection of such preparations into rabbits. A search continues for a better plant than dahlia in which to culture the virus. No specific zones were visible in density gradient centrifugation of such preparations.

Tomato mosaic (L. Broadbent)

The epidemiological study of this disease was continued. The survey of commercial tomato crops, in co-operation with N.A.A.S. officers and growers, has been concluded. Of 203 samples of foliage sent in during 1960 and 1961, 187 were infected with a strain of tobacco mosaic virus causing tomato mosaic, which differed from the strains found in smoking tobacco. A tobacco strain was found only in four samples of grafted plants from one nursery. Although all 40 brands of cigarette tobacco tested, 13 of 15 cigars, and seven of nine pipe tobaccos, were infected, it is clear that smoking tobacco is seldom a source of TMV in British tomato crops. This is because the virus concentration in tobacco is low and handling dry tobacco seldom contaminates the hands; also the tomato strains of TMV often protect the plants against infection with the tobacco strains.

Contamination of seeds by TMV is more complicated than was at first apparent and work on this is being continued. Only a proportion of seeds from infected fruits carry much virus, and treatments such as acid cleaning which eliminate virus from some batches of seeds fail to do so from others. Further work has confirmed that "seed-transmission" of virus occurs during pricking-out the seedlings, and does not occur if the young plants are not disturbed. Soaking infected seeds in tri-sodium orthophosphate inhibits infection, but does not inactivate the virus as do hydrochloric acid, Teepol and heat treatments.

More evidence was obtained that more plants became infected early when the soil had been treated with the chemical sterilants, chloropicrin and metham-sodium, than when it was untreated, and that careful steaming eliminated virus from soil.

No evidence has been obtained from many tests that TMV over-winters on glasshouse structures. It may persist for many months on clothing in darkness, but it is soon inactivated in daylight.

It has been suggested that spraying infected tomato plants with a solution of urea would help them to overcome the effects of TMV. Two extensive experiments were done to test this, in co-operation with the Chemistry Department. Details of the spray treatments will be found on pages 51–2. Weekly spraying with urea or urea plus organic salt solutions had no significant effect on virus disease symptoms or fruit number. As in 1960, TMV induced necrotic pitting, bronzing and severe mottle in fruits that were well grown at the time of infection, but not in those that set after systemic invasion had occurred.

An experiment on losses in yield due to infection with TMV, in tomatoes grown in unheated structures, was sponsored at the Efford Experimental Horticulture Station, and will be repeated during the next two years.

Work has begun, in co-operation with the Horticulture Department, on the effects of TMV on the growth of tomatoes at different times of the year, i.e., in relation to daylength. The responses of tomato plants to different isolates of TMV are also being studied.

GENERAL TECHNIQUES

Serology and virus purification

1. Stabilisation of a plant virus antigen by formalin treatment (M. Hollings and Olwen M. Stone)

Celery yellow vein (CYVV), beet ringspot and tomato black ring viruses are serologically related strains. All three viruses reach a high concentration in *Nicotiana clevelandii* in about 14 days, and can be purified by the butanol-centrifugation method to give preparations that are highly infective, contain many "spherical" particles and produce similar light-scattering zones in density gradient centrifugation. Whereas preparations of beet ringspot virus, with or without adjuvant, when injected into rabbits, produced antisera with titres up to 1/5,000, injection of similar preparations of CYVV elicited no antibody response; yet the preparations of CYVV reacted almost to titre in precipitin tube tests with antiserum to the beet ringspot strain.

When treated with formalin to 0·2% concentration, infectivity of CYVV was practically abolished, whereas the serological titre in precipitin tube tests, and the intensity of zone formation in density gradient centrifugation were unimpared.

Two intramuscular injections into rabbits of such formolised preparations of CYVV, that had been emulsified with Freund's adjuvant, produced antiserum with a titre of 1/1,520 against the homologous antigen but no reaction against control preparations from healthy plants. Comparison in gel-diffusion slides of the reaction lines of formolised and untreated preparations of CYVV, beet ringspot and tomato black ring viruses showed complete continuity of the reaction lines. Similar continuity was found between the reaction lines of CYVV preparations with both the homologous and beet ringspot antisera.

Although we are not concerned with celery yellow vein virus as a plant pathogen, it provided a suitable system for studying serological techniques; there are many plant viruses against which antisera have not yet been made, and the stabilisation of the antigen preparations with formalin may help. However, an antiserum made against arabis mosaic (isolated from *Sambucus niger*) using formolised antigen proved no better than those made in the normal way.

2. Density gradient centrifugation (M. Hollings, Olwen M. Stone and Margaret E. Norrish)

Work has continued on the purification and analysis by density gradient centrifugation of several viruses. We have adopted for routine work a method that gives sedimentation approaching equilibrium: the gradient column comprises 5 ml. each of 10, 20, 30 and 40%, and 10 ml. of 50% sucrose in M/30 phosphate buffer, *p*H 7·6. After overnight storage at 0°C., virus preparations are layered on top of the liquid column, and the tubes centrifuged for two hours at 25,000 r.p.m. in the Spinco R25 rotor. This has given cleaner separations than rate-zone centrifugation with our preparations.

Specific zones, which contained most of the infectivity and/or serological activity, were obtained from 21 viruses: mottle, ringspot, latent, vein mottle, lucerne mosaic and CIR viruses from carnations; virus B, vein mottle, and aspermy from chrysanthemum; cucumber mosaic

virus; tomato black ring and its beet ringspot and celery yellow vein strains; celery yellow net virus; arabis mosaic and its cucumber stunt mottle strain; pelargonium leaf curl, tomato bushy stunt, turnip crinkle, a virus from white clover, tobacco mosaic and a virus from narcissus.

We failed to obtain specific zones with some viruses: dahlia mosaic, chrysanthemum ring pattern and pea mosaic gave no visible zones, while zones produced by chrysanthemum viruses D, E and stunt were not consistent and we lack suitable assay methods to determine their specificity.

Density gradient centrifugation is a useful technique for revealing unsuspected mixtures of viruses and indicating possible similarities or relationships between viruses from different plants. We have prepared antisera by injecting rabbits with virus zones extracted from gradient columns and such antisera have proved highly specific.

The formation of multiple zones has occurred with several viruses, and differences in virulence have been found in inoculation from the different zones, yet after passaging several times through plants no distinction could be seen between isolates from the different zones.

3. The relative sensitivity of different methods of detecting viruses (M. Hollings and Olwen M. Stone)

This has been studied using infectivity, serological activity in precipitin tubes, micro-precipitin drop, and gel-diffusion tests and the production of specific zones in density gradient columns.

The results showed that, where suitable test plants were available, infectivity tests were consistently more sensitive than any serological test. Zone production in density gradient centrifugation was closely parallel to serological reaction, though not necessarily dependent on infectivity. Infectivity could be detected outside the visible zones and non-infective preparations could give zones. The most sensitive and reliable serological test was the precipitin tube method, but gel-diffusion slide tests were very valuable in the study of virus and strain relationships, and in separating mixtures of viruses.

4. Intracellular inclusions (Margaret E. Norrish)

Attempts to correlate inclusion type with specific viruses have begun, using carnation seedling clones experimentally infected with vein mottle virus alone. In epidermal strips taken four months after infection, the nuclei of infected plants appeared more granular and, when measured, were significantly larger than nuclei from healthy control plants. Granular "amoeboid" inclusions, distinct from the nucleus, were first visible eight months after infection, and their development is being studied.

Production of virus-free plants (Olwen M. Stone)

More batches of carnations were heat treated during the year and tips were taken from them and, as control, from plants grown at normal glasshouse temperatures. Larger culture tubes (3 in. x $\frac{5}{8}$ in.) were used and a liquid medium with a filter paper wick was used in preference to agar. Rooting was better in these tubes than in agar cultures, possibly because there was better aeration. The initial nutrient solution contained a rooting hormone (NAA), but as soon as roots had been formed the tips were transferred to fresh tubes containing nutrient solution without rooting hormone. Thus there was not the check to growth that would have occurred through prolonged exposure to the rooting hormone.

Inoculation tests to *Chenopodium amaranticolor* again showed that some meristems were apparently free from mottle virus but that tips $\frac{1}{2}$ to 1 mm. long contained considerable quantities

of virus. Nevertheless, when tips were taken from similiar plants and grown in tubes some of the resulting plants had no detectable mottle virus in them. Further tests are in progress to follow the concentration of mottle in excised growing tips.

Heat-treated tips rooted more readily than tips from control plants, but not all the heat-treated tips produced virus-free plants. Sometimes mottle was readily detectable in plants which had grown sufficiently large to be tested, in others the mottle virus appeared to have been "attenuated" (see special article on page 100). The occurrence of the attenuated type of mottle virus emphasises the importance of repeated and careful testing of plants from tip culture before claiming that they are virus free.

Some clones of varieties 'Cocomo Sim', 'Joker', 'Orchid Beauty' and 'Pink Shibiuya', obtained by meristem culture, have shown no symptoms for up to a year. Repeated indexing did not detect in them any of the eight viruses for which reliable tests exist.

Ringspot virus was eliminated when tips were taken, without heat treatment, from infected carnations.

A few tips were taken from dahlia plants infected with dahlia mosaic virus. These tips did not grow as readily as carnation tips and tended to form large calluses but no roots. Three tips produced roots with small tubers but no shoot, and it is probable that a different light regime is required before shoots will develop.

9. CROP PROTECTION

by

W. H. READ

Investigations on the control of the Glasshouse Red Spider Mite have been continued in the laboratory and in the cucumber trial houses. The Entomology Department has collaborated in a number of these studies.

Work on fungicides has been concerned with the problem of adequately controlling Narcissus Leaf Scorch without spray damage, and the most effective fungicide programmes for controlling Chrysanthemum Petal Blight and Cucumber Powdery Mildew.

Trials with new compounds not yet accepted as free from hazard to consumers of edible produce must obviously be somewhat restricted as all fruit on which there may be residues must be discarded. In order to assist in deciding whether certain compounds showing merit can be accepted for use on cucumbers a start has been made in determining the residues of the two most promising compounds on sprayed cucumbers.

The third consecutive comparative trial with steam, chloropicrin and metham-sodium has been made, and investigations on the distribution and rate of elimination of methyl isothiocyanate from soil, and the toxicity of this compound to plants, have been associated with this trial.

Glasshouse Red Spider Mite (Tetranychus urticae Koch)

Control on cucumber (W. H. Read and Valerie A. Cooke)

(a) *Sulphur vapour.* The vaporisation of sulphur nightly at the rate of 0·5 g./1,000 cu.ft. to control Cucumber Mildew was considered responsible for the failure of mites to colonise plants in the trial cucumber houses in 1960. Experiments were therefore made in 1961 to find if satisfactory control of Red Spider Mite could be obtained by vaporising sulphur, commencing with nightly vaporisation at rates of 1·0 g. and 0·25 g./1,000 cu.ft. in two separate glasshouses. Climatic conditions in these two houses, and a third glasshouse in which sulphur was not used, were kept as uniform as possible.

It became apparent after three weeks that the vaporisation of sulphur at 1·0 g./1,000 cu.ft. nightly was much too injurious to the plants to be acceptable, the older leaves becoming prematurely senescent, scorched areas appearing on the younger leaves, and the growth becoming harder. The dosage was therefore reduced to 0·5 g./1,000 cu.ft.

Two alternative methods of assessing mite populations were examined in these houses. One was based on periodically counting the numbers of mites in selected colonies *in situ*, colonies being selected in which there were 5–10 active female mites—usually accompanied by some nymphs and eggs—on young leaves on lateral growths. These colonies were marked and their development recorded by counting the mites periodically *in situ*. In the other method leaf discs, 1·5 mm. diameter, were taken at seven-day intervals from leaves on randomly selected plants at a number of levels, these levels being delineated by the horizontal wires supporting the plants. Leaves of corresponding position in relation to the plant—e.g., main stem leaves or first leaf on a lateral, etc.—were used and the discs taken from similar positions on the leaves. The numbers of dead and live mites and eggs on the discs were recorded. The second method proved more satisfactory as it gave a better estimate of the degree of infestation of the plants and was much more convenient as the mites were counted in the laboratory.

Although the mite populations on plants subjected to sulphur vaporisation were lower than on those not subjected to the treatment, they reached levels sufficient to cause severe injury to the plants. The prolonged vaporisation of sulphur at 0·5 g./1,000 cu.ft. also appeared to cause some hardening of the plants.

At this stage it is impossible to suggest a reason why the promising results obtained with sulphur in 1960 were not repeated in 1961.

(b) *Other acaricides.* A number of new compounds and products were examined in the search for new acaricides which might be of value against strains of mites resistant to those now in use for controlling Red Spider Mite on cucumbers.

Of these, the following were found highly active and equally effective against non-resistant mites and a strain of Red Spider which is highly resistant to organo-phosphorus compounds and slightly resistant to Kelthane: 2-sec butyl-4, 6-dinitrophenyl-3, 3-dimethyacrylate (Hoescht 2784), quinoxaline-2, 3-diyl-trithiocarbonate (to which the common name thioquinox has been given), and the related compound 6-methylquinoxaline-2, 3-diyl-dithiolcarbonate (Bayer Ss 2074).

Tests on young pot cucumber plants showed that Hoescht 2784, formulated as an emulsifiable concentrate, was phytotoxic at concentrations exceeding 0·006%, and thioquinox and Ss 2074, formulated as dispersible powders, were phytotoxic at 0·025%. Control of adult female mites was obtained in laboratory tests with these compounds at 0·003%, 0·007% and 0·002% respectively. Older plants were much more tolerant than young plants, and these compounds were selected for further trial on planted-out plants, at 0·01% with Hoescht 2784 and at 0·05% and 0·025% with thioquinox and Ss 2074, in comparison with petroleum emulsion at 0·65% petroleum and an emulsion of polybutenes (polymerised butylenes of viscosity 44000 SSU/100°F.) at 0·75% active material.

This trial showed that a moderately severe infestation by a resistant strain of mites could be controlled by three thorough applications of these sprays at fortnightly intervals. Although yields of cucumbers were greatest from plots sprayed with thioquinox and Ss 2074, this may reflect the action of these compounds in controlling Cucumber Mildew rather than phytotoxic effects of the other acaricides *per se* or in combination with dinocap which had to be applied to control mildew on plots sprayed with petroleum, polybutene and Kelthane. Thioquinox and Ss 2074 did not control the leaf fungus *Trichothecium roseum* which seriously affected the plants towards the end of the trial.

The efficiency of spraying was undoubtedly higher than that on many commercial nurseries. No translaminar action, whereby mites on the undersides of leaves are killed by the application of the acaricide to the upper leaf surface, was shown by Hoescht 2784, thioquinox or Ss 2074. The first of these compounds was unsatisfactory when applied as an aerosol. Further trials are necessary to determine the optimum concentrations of these compounds and their effect on cucumbers under a variety of conditions, and it has yet to be established that the quinoxaline derivatives are safe for application to edible crops.

A number of grades of polybutenes of different viscosities were emulsified and compared with a petroleum emulsion in trials on mite-infested cucumbers. At 1·5% and 0·75% polybutenes all grades gave good control of mites, but at 0·37% the control was inadequate. There was no consistent difference between the degree of control obtained with polybutenes at the two higher concentrations and that given by 0·65% petroleum. It is apparent that the failure of commercial growers to control Red Spider Mites satisfactorily on cucumbers with some sprays may be due to the great practical difficulties in obtaining adequate cover of the foliage, particularly with substances which have little or no persistent residual action or translaminar effect on mites.

Although residual films of polybutenes impart a tackiness to sprayed leaves, measurement of the practical value of this property in trapping mites which may have escaped direct contact with the spray is difficult since it is influenced by factors causing mite movement. Under normal conditions, where the infestation is not so severe that a high proportion of the mites are actively moving in search of food, the stickiness of polybutene deposits on cucumber leaves sprayed with polybutene emulsions at 1·5% and 0·75% was of very limited duration, except in the vicinity of the main veins, and did not appear to contribute appreciably to the practical value of such sprays. Adequate coverage of the foliage is consequently of great importance with physically acting acaricides of this type. Unsatisfactory results were obtained by applying petroleum or polybutenes by low volume methods.

Control on carnation (Valerie A. Cooke)

The investigations on the control of Red Spider Mite on carnations made in 1959–1960 have been brought up to date by examining the value of several recently introduced organophosphorus compounds against the pest on this host. Menazon [S-(4, 6-diamino-1, 3, 5-triazin-2-yl methyl) diethyl phosphorothiolothionate] and phosphamidon [2-chloro-2-diethylcarbamoyl-1-methyl vinyl dimethyl phosphate] were compared with demeton-methyl which is commonly used for the control of Red Spider Mite on carnations. Tests on plants in 6 in. pots showed that when applied as drenches (50 ml./pot) demeton-methyl at 0·04% controlled the mite and prevented re-infestation for a period of 17 days. Phosphamidon did not give complete control of mites at 0·04%; Menazon, as anticipated, had no systemic action in carnations against Red Spider.

Later in the year these compounds were compared as sprays at concentrations of 0·04%, 0·02% and 0·01%, together with oxydemeton-methyl [S-2-(ethylsulphinyl)-ethyl dimethyl thiophosphate] at 0·02%, 0·01% and 0·005%. Demeton-methyl and oxydemeton-methyl at all the concentrations used gave 100% control of mites after four days and prevented re-infestation of the plants for eight days after application. Demeton-methyl at 0·04% and oxydemeton-methyl at 0·02% caused over 70% mortality within five days of mites placed on the plants 24 days after spraying, the latter spray giving marginally better results than the former.

Phosphamidon at 0·04% gave 100% control, and at 0·02% and 0·01% over 90% control, within four days, but its action was less persistent. Menazon at 0·04% gave less than 50% control after four days and had very little residual effect after that period.

Examination of the plants after 45 days showed that those treated with menazon and phosphamidon were heavily infested, but few colonies of living mites were found on plants sprayed with 0·04% demeton-methyl and 0·02% oxydemeton-methyl, even though attempts were made to re-infest the plants with mites at intervals up to 31 days after spraying.

None of the compounds caused injury when applied as sprays or drenches at the concentrations referred to in this section.

Oxydemeton-methyl, which spraying tests showed to be about twice as potent as demeton-methyl against Red Spider on carnations, has considerably less odour than the latter and no unpleasant smell is discernible on carnation flowers shortly after spraying.

Resistance to Kelthane (Valerie A. Cooke)

A repeatable laboratory method of estimating small degrees of resistance to Kelthane was required in connection with investigations on Kelthane resistance of Red Spider Mite. Methods based on counting the numbers of dead and living mites after the application of a range of

concentrations of this compound by dipping, spraying or aerosol are unsatisfactory where the degree of resistance is slight.

One method examined involved keeping adult female mites on cucumber leaf discs precisely sprayed with an emulsion of Kelthane at concentrations ranging from 0·01% to 0·1%. The estimation of the percentage mortality of the mites so treated was subject to error as many mites were only moribund or semi-moribund when counts were made after four days and their classification as dead or alive was difficult. Lengthening the period during which the mites were kept on the discs introduced other sources of error.

It was possible, however, to prepare probit-regression lines from the data obtained and establish differences in strain responses to Kelthane. A strain of mite which had an LD50 concentration more than 50 times that of the parent mites was selected by the repeated application of increasing concentrations of Kelthane.

In the course of this work it was noticed that fewer eggs were laid by females placed on treated discs than on untreated discs during the first 30 hours, during which time all the mites were active. The reduction in the number of eggs was greater with increasing amounts of Kelthane on the discs. Strains which showed most resistance to Kelthane, as indicated by the probit-regression lines referred to above, tended to lay most eggs during this period. A method of assay based on the number of eggs laid over a relatively short period would have several advantages, but more work is required to establish whether such a method will prove reliable and reproducible.

Thioquinox residues on cucumber (R. J. Smith)

In view of the promising results obtained with thioquinox (quinoxaline-2, 3-diyl-trithiocarbonate) against strains of Red Spider Mite highly resistant to organo-phosphorus compounds and slightly resistant to Kelthane, it was considered important to find what residues of this compound were likely to be present on sprayed cucumbers. Information on the persistence of thioquinox on sprayed cucumber foliage is also desirable.

The suitablity of a colorimetric method of analysis based on that of Skoog, Ming-Gon Lai and Furst (1958) for the determination of nickel with 2, 3-dimercaptoquinoxaline was investigated. The method, adapted by Tietz, H., Osman, M. F., Frehse, H. & Niessen, H. of Messrs. Bayer A. G., Leverkusen, to whom we are indebted for particulars, depends on the formation of a coloured nickel complex with the 2, 3-dimercaptoquinoxaline resulting from the saponification of the quinoxaline trithiocarbonate by ammonia in the presence of sodium sulphide. The procedure was found satisfactory for the estimation of thioquinox residues on cucumbers.

Preliminary estimates of thioquinox, on cucumbers harvested in November one or two days after spraying with this chemical formulated as a dispersible powder and applied at 0·05%, showed that residues of less than 1 p.p.m. were present. Further estimations of the amounts and persistence of residues of thioquinox, and of the related 6-methylquinoxaline-2, 3-diyl-dithiolcarbonate, will be made in 1962.

Cucumber Mildew control (W. H. Read and Pauline M. Smith)

The results of large scale trials in which sulphur was vaporised nightly at the rate of 1 oz./50,000 cu.ft. confirmed the preliminary results obtained in 1960. The use of sulphur at this rate gives good control of Cucumber Mildew but appears to harden the plants and may cause some leaf-scorch in the vicinity of the vaporisers. Reduction of the dosage to $\frac{1}{2}$ oz./50,000 cu.ft. resulted in inadequate control under the conditions of the trial.

As Red Spider Mite was not controlled by the higher rate of sulphur vaporisation, alterna-

tive mildew control measures using substances more compatible than sulphur with petroleum are desirable or, better still, other acaricides which are effective against resistant strains of mites and also effective in controlling Cucumber Mildew.

Of the the substances tested against Cucumber Mildew the most promising were thioquinox and the related compound Bayer Ss 2074. Although the compound H 2784 was also effective against Cucumber Mildew at 0·05% it was phytotoxic to young plants at 0·01%. Variable results were obtained with a number of polymerised butylenes (Polybutenes) of differing viscosities when applied as emulsions at 1·5%. At 0·75% they caused only a slight check to the development of Powdery Mildew on plants infected at the time of spraying and little protection from infection.

The value of these compounds was further examined where they were used in trials against Red Spider and the host plants became infected with Cucumber Mildew during the establishment of the mites.

The control of mildew by thioquinox and Ss 2074 at 0·05% and 0·025% was superior to that given by dinocap at 0·01% or H 2784 at 0·01%. In order to safeguard the Red Spider trial from the effects of mildew it was necessary to spray all the plots with dinocap except those sprayed with thioquinox and Ss 2074. Plants sprayed with these two compounds were more vigorous and produced higher yields than those sprayed with petroleum emulsion and dinocap, Polybutenes and dinocap, H 2784 and dinocap, Kelthane and dinocap or with dinocap alone.

A method of rooting detached cucumber leaves has been used to obtain successive batches of uniform host material suitable for precise spraying in the assay of chemicals for the control of Cucumber Mildew. The petioles of detached leaves are inserted in shallow tanks of moist vermiculite kept at 24°C. (75°F). When kept under mist in a glasshouse at 15–18°C. (60-65°F.) root initials are formed in five days, and leaves are sufficiently rooted for use in fungicide tests seven days after their removal from the host plant.

Chrysanthemum Petal Blight (Pauline M. Smith)

Trials with fungicides for the control of Chrysanthemum Petal Blight (*Itersonilia perplexans*) have frequently failed in the past owing to the difficulty of obtaining infection of unsprayed blooms. A method of providing conditions suitable for the infection of trial plants has therefore been devised.

In conjunction with the Mycology and Bacteriology Department trials have begun to assess the efficiency of fungicides and of alternative methods of application for the control of Petal Blight.

Zineb at 0·1%, prepared by the interaction of nabam and zinc sulphate in the spray tank, was superior to captan at 0·1% and thiram at 0·3%. When applied at high volume to chrysanthemum *var.* 'Penrod' at two-day intervals 0·1% zineb gave 75% control of the disease, whereas 1·0% zineb applied at low volume at two-day intervals gave 52% control; in both cases the control lasted over a period of 19 days during which the plants were re-inoculated with *Itersonilia* spores on the non-spraying days.

Zineb at 0·1% high volume and 1·0% low volume were relatively ineffective when applied at four- and eight-day intervals under conditions of frequent re-inoculation, giving about 40% control at four-day intervals and 18% at eight-day intervals.

The 0·1% zineb applied at high volume caused slight to moderate spotting of the outer petals of 'Penrod' when applied every two days to the opening flowers.

Narcissus Leaf Scorch (Pauline M. Smith & R. J. Smith)

Further study of the biology of *Stagonospora curtisii* has shown that the mycelium persisting on the dormant bulb, between the papery and fleshy scales, causes the primary leaf-tip infections on the emerging leaves the following season. There is some evidence that soil which has carried a diseased crop may remain infective the following year.

Misting equipment has been installed in a glasshouse making it possible to infect narcissus foliage with Leaf Scorch by spraying with a suspension of *Stagonospora* spores, and therefore facilitating the trial of fungicides. However, difficulty has been experienced in consistently producing phytotoxicity with Bordeaux mixture either alone or in conjunction with misting with sea water. Damage occurred more frequently when Bordeaux was applied to mature foliage after flowering, and was increased by bruising the leaves (to simulate wind damage) before spraying.

The addition of an emulsified polyvinyl acetate slightly reduced the phytotoxicity of Bordeaux and improved the protective action of zineb. Certain absorbents also appeared to reduce phytotoxicity when added to Bordeaux. Phenyl mercury acetate at 0·01% and dichlone at 0·2% gave good control of Leaf Scorch but proved phytotoxic.

Determinations of the amounts of cuticular wax on leaves of different varieties of narcissus at different stages of growth have been made in connection with a study of factors affecting susceptibility to attack by *Stagonospora.*

Soil sterilisation studies (J. T. Hughes, W. H. Read & R. J. Smith)

Comparison of metham-sodium, chloropicrin and steam as soil sterilants

The treatments first applied in 1958 were again applied to the same plots for the 1961 crop. As in 1960 two varieties, 'Potentate' and 'Moneymaker', were grown. Normal cultural conditions were given, and all plots received the same amounts of base fertiliser and post-planting fertiliser. Although yields (see table I) were lower than in previous years, partly because of the early removal of the plants, they were in agreement with those obtained in previous years.

TABLE I

SOIL STERILISATION EXPERIMENT: MEAN YIELDS PER TREATMENT IN 1961 WITH THOSE OF 1959 AND 1960 FOR COMPARISON

Treatment	Yield (*lb./plant*)				1959
	1961		1960		
	'Potentate'	'Moneymaker'	'Potentate'	'Moneymaker'	All varieties
Steam	8·25	9·01	11·13	11·79	9·75
Chloropicrin	8·30	9·04	10·93	11·66	9·63
Metham-sodium	7·81	8·35	10·26	11·28	9·48
Control	4·57	4·97	6·03	6·58	7·25
Sig. diff. ($P=·05$)	0·73		1·18		0·44

The severity of corky root and brown root rot on the roots when the plants were removed was significantly less on plants from the steamed plots than on those from the metham-sodium treatment. All sterilisation procedures resulted in significantly less disease than in the unsterilised control plot. Growth differences at different stages suggest that roots in the sterilised

plots become infected by corky root and brown root rot later than those in the unsterilised control plots, possibly because of re-infection of the soil from below.

Determination of residues of methyl isothiocyanate in soil

In the method already reported (*Rep. Glasshouse Crops Res. Inst., 1960, p. 81*) the addition of ethyl alcohol to the soil-water mixture was recommended. Its use evolved from the two-fold consideration of reducing losses of the highly volatile methyl isothiocyanate and of making possible the observation of UV spectra of the same distillate with and without ammonia treatment. When this method is applied to the determination of methyl isothiocyanate residues in soils treated with metham-sodium in the field, interference may occur, particularly with samples from the surface layers after drench applications, consisting of an opalescence which clarifies and turns slightly yellow on treatment with ammonia, finally becoming colourless. After standing for several hours the absorbance ($\lambda = 235\,m\mu$) of such distillates, which decreases to a constant value, probably approximates to that of the more strongly absorbing N-methyl-thiourea present. However, spectra usually show fairly generalised absorption decreasing steeply from shorter wavelengths through the region of the methyl-thiourea peak which may be present as a point of inflection or even absent.

The interference has been entirely eliminated by omitting the ethyl alcohol and using a wholly aqueous steam-distillation procedure. Good recoveries are ensured by attaching a glass delivery tube, fitted with a coarse sinter or glass-wool plug, to the condenser outlet with a glass joint; this dips directly into 10 ml. of 1:1 ammonia solution in the receiver (a 25 ml. graduated test tube), and 10 ml. of distillate are collected from 10/25 g. moist soil mixed with 50 ml. water.

In this form the method has been successfully employed to study the persistence and distribution of residues of methyl isothiocyanate in soil after various methods of treatment, and characteristic spectra for N-methylthiourea were consistently obtained even when residues had decreased to as little as 2 p.p.m. several weeks after application. In these experiments none of the interference previously mentioned was observed in upwards of 500 individual determinations.

Results are given which show the recoveries obtained of known amounts of methyl isothiocyanate distilled from aqueous solution or from soil as described above. Recoveries are calculated by reference to (a) known amounts of N-methylthiourea and (b), known amounts of aqueous methyl isothiocyanate. The soil blank is equivalent to *ca.* 10 μg. methyl isothiocyanate. i.e., $< 0{\cdot}5$ p.p.m. (see table II).

TABLE II

RECOVERY OF METHYL ISOTHIOCYANATE BY AQUEOUS STEAM DISTILLATION PROCEDURE

Test	Taken (μg)	Soil (*ppm*)	Found (a)		Found (b)	
			μg	%	μg	%
Aqueous solution (50 ml.)	48	—	41	86	46	95
	96	—	84	87	93	96
	144	—	131	91	145	100
	192	—	169	88	187	97
	240	—	208	87	230	96
25g. soil and water (50 ml.)	67	2·7	54	81	63	94
	135	5·4	116	86	135	100
	202	8·1	179	89	209	103
	269	10·8	228	85	266	99

The method as described is equally suitable for the estimation of residues from the application of methyl isothiocyanate formulated in xylene ("Trapex"). *O-*, *m-* or *p-* xylene, even if present, would cause negligible interference as they absorb comparatively weakly at their absorption maximum of 266 mμ, and at 235 mμ the absorption is at an even lower minimum value. An experiment in which known amounts of methyl isothiocyanate in the presence of four times these amounts of xylene were determined by the direct addition of ammonia gave the following results:—

TABLE III

DETERMINATION OF METHYL ISOTHIOCYANATE IN THE PRESENCE OF XYLENE

CH_3NCS	Xylene	CH_3NCS found			
		(a)		(b)	
(μg)	(μg)	μg	%	μg	%
40	160	36	89	41	101
80	320	73	91	82	103
120	480	110	92	125	104
200	800	181	91	206	103

Distribution studies—metham-sodium

The distribution of methyl isothiocyanate in soils resulting from the application of metham-sodium by several suggested methods has been studied in order to determine the most satisfactory method of application.

Injection of the concentrated 39% w.v. metham-sodium solution unaccompanied by any immediate cultivation resulted in unsatisfactory lateral and vertical distribution. The application of the concentrate diluted ×16 to the surface of the soil, followed immediately by rotary cultivation, provided adequate distribution in the soil to a depth only slightly exceeding the depth of cultivation and was less satisfactory than where an equal amount of metham-sodium concentrate was diluted ×200 and applied as a drench. The greatest depth of penetration was obtained where a solution of methyl isothiocyanate was applied to the bottom of the trench as digging proceeded.

The rates of disappearance of methyl isothiocyanate from soils, the effects of soil moisture on its absorption and desorption by soils, and the relative values of the different methods of application on tomato yields are being investigated.

Phytotoxicity studies

Studies of the phytotoxicity of the products resulting from the decomposition of metham-sodium in the soil showed that concentrations of methyl isothiocyanate not exceeding 5 p.p.m. were not injurious to the roots of young tomato plants and caused no growth modifications. At concentrations exceeding about 7 p.p.m. in the soil tomato roots were injured, with partial or complete collapse of the stem at higher concentrations. N-methylthiourea and N, N'-dimethylthiourea caused no evident modification in the growth of tomatoes grown in soil containing 10–200 p.p.m., but caused root injury at concentrations exceeding about 50 p.p.m.

When young tomato plants were kept for 17 hours on 3–5 successive overnight periods in an atmosphere containing 0·01 g./1,000 cu.ft. of methyl isothiocyanate, growth modifications occurred after an interval of a few weeks. Partial or complete suppression of both main and side shoots resulted, with occasional substitution of a flower truss for a normal axillary (side) shoot. Such flower trusses usually produced normal, fertile flowers, but trusses which were

formed when the plants were exposed to methyl isothiocyanate vapour failed to produce their normal fertile flowers.

In the furtherance of work on the phytotoxicity of methyl isothiocyanate a simple chemical method of detecting traces of this compound in the air has been devised. The usefulness of this test for indicating when tomatoes can be safely planted out in glasshouses treated with metham-sodium or methyl isothiocyanate is being investigated.

REFERENCE

SKOOG, D. A., MING-GON LAI & FURST, A. (1958). Quinoxaline-2, 3-dithiol as a colorimetric reagent. Determination of nickel in ammoniacal solutions. *Anal. Chem.*, **30,** 365.

10. HORTICULTURE

by

G. F. SHEARD

The programme of work on tomato growth control, tomato fruit ripening problems, mushroom cultivation, loamless composts, planting density of carnations, and nutrition of early flowering chrysanthemums has continued from 1960. With the promotion of Mr. Z. J. Kulwiec to Assistant Experimental Officer and his transfer to the Department it has been possible to increase the work on loamless composts. Some preliminary work has been done on the keeping quality of cut flowers. Consideration has been given to the extension of this work and to the development of work on problems connected with the production of hardy nursery stock.

Progress has been made in instrumentation to continuously record environmental conditions in glasshouse experiments, and it is hoped to start continuous records of solar radiation in the near future.

Visit to Holland

Mr. G. F. Sheard spent two weeks in Holland in March. Visits were paid to the Institute of Horticultural Engineering, the Horticultural Laboratory, and the Institute of Horticultural Plant Breeding at Wageningen, the Experimental Station at Naaldwyjk, and commercial glasshouse holdings in the province of South Holland.

Tomato growth studies (A. J. Cooper)

The experiment designed to determine the relation between the date of sowing, time of year and the pattern of development of the tomato, begun in 1959, was completed during the year. Fifty-six successive sowings were made at weekly intervals and the plants grown to an age of about 12 months. The rate of development of all the organs was measured at weekly intervals.

Analysis of the data on fruit development has been completed and is the subject of a special report at page 109. This work showed that the pattern of development can be divided into five distinct phases: (a) an initial phase from germination to the start of fruit development, (b) an initial period of low fruit volume production, (c) a period of rapidly increasing production, (d) a period of declining production, and (e) a dormant period in which fruit swelling virtually ceases. The duration of the period from germination to the start of fruiting was related to the daylength, the relation being hyperbolic with asymptotes at 10–10½ hours and 50–57 days. At daylengths below 10 hours little or no progress was made toward fruiting. With increasing daylength the period to fruiting shortened to a minimum of about 50 days. The dormant condition occurred in mature plants from the shortest day to the vernal equinox. In juvenile plants dormancy was induced when the duration of darkness exceeded that of light and was maintained from about the autumnal equinox to the vernal equinox. In both juvenile and mature plants dormancy was broken when the duration of light exceeded that of darkness, and this was followed by a period of rapidly increasing fruit volume production. During this phase the rate of production was related to daylength and was curvilinear. The rate of production continued to increase so long as the daylength increased. When daylength began to decline so did the rate of production, the relation becoming linear.

Dormancy in the tomato is manifested by the arrest of reproductive activity. The gradual transition into a dormant condition in late October and the rapid emergence from dormancy in March coincides in timing with the seasonal pattern of other forms of dormancy in other plants. This raises the speculation whether the interaction of a hyperbolic daylength response

curve with the annual parabolic curve of change in daylength may be the cause of winter dormancy and whether, in consequence, the phenomenon may be of wider application than being merely specific to reproductive activity in the tomato.

Reproductive activity and vegetative growth

During the year work was carried out to investigate the relation between reproductive activity and vegetative growth. The following treatments were applied:—

(a) No leaves removed
(b) Alternate leaves removed as they appeared
(c) All leaves removed as they matured

Each of the three main treatments was split four ways:—

(i) No fruit removed until ripe
(ii) Alternate fruits removed as soon as they began to swell
(iii) Only one fruit allowed to develop
(iv) All inflorescences removed as soon as the flower buds were visible

Measurements of the development of all organs were made at weekly intervals.

The weekly rate of vegetative growth, as estimated by shoot extension growth and leaf area production, progressively increased each week from germination until the start of ovary swelling. Vegetative growth was checked about the start of ovary swelling, but the magnitude of the check was not proportional to the fruit load borne by the plants, the weekly rate of vegetative growth being similar in all the treatments allowed to bear fruit. Plants from which the flower buds were removed showed an identical check suggesting that the check is not causally related to ovary swelling. If the check is causally related to reproductive activity, the internal mechanism causing the check must be stimulated between the initiation of floral primordia and the visible appearance of flower buds, the interval between the initial stimulus and its effect being such as to give a check to vegetative growth about the time ovary swelling occurs or would occur.

The data are still being analysed, and while conclusions cannot yet be drawn it was clear that the treatments markedly altered the form of the plants, though not the rate of vegetative growth. The removal of flower buds and the prevention of fruiting caused a large increase in stem diameter and a very pronounced epinasty. The epinasty was very similar in form to that caused when the concentration of growth regulating substances within the plant is artificially raised. The removal of alternate leaves caused a marked reduction in shoot extension growth.

Leafing

Previous work showed that a constant ratio of fruit volume prduction to leaf area production was established once fruiting began. This suggested that de-leafing, as practised in commercial nurseries, might possibly be detrimental. A trial was therefore carried out comparing four degrees of leafing. Analysis of the data has not been completed, but a preliminary examination of the results suggests that the yield was slightly reduced by de-leafing.

Root restriction

For early sowings and plantings growers have for many years practised root restriction as an aid to ensuring a satisfactory early crop. Work has been started to investigate the effect of different degrees of root restriction on sowings made in mid-October. An analysis of the 1961 results is incomplete, but it is clear that increasing root restriction increases the chance of producing a satisfactory flower truss in the dormant period. The work has indicated that the prob-

lems of early fruit production can be split into two distinct groups: (i) production and development to flowering of a satisfactory truss, and (ii) setting of the flowers produced. Root restriction seems to be mainly concerned with the first phase; temperature—and possibly humidity—with the second. Little is known about the conditions needed for setting in the dormant period, and the present work indicates a need for study in this field.

Tomato fruit-ripening disorders (A. J. Cooper)

The first phase of the work on fruit ripening disorders sponsored at the Lee Valley Experimental Horticulture Station was completed at the end of 1960 and a paper describing the results is in the press. The work was extended in 1961 to include potash level as a fourth factor.

Controlled daylength chambers (A. J. Cooper)

In collaboration with the Instrument Technician an automatic daylength controller has been developed. This will give control of daylength, and rate of change of daylength, and can be used to simulate seasonal changes in daylength under long day conditions. Work is now in progress to improve the control of environment inside the chambers, on completion of which they will be used to test the relation between tomato development and light duration for causality.

Mushrooms (P. B. Flegg)

Environmental studies

Experiments in the controlled environment cabinet have been continued jointly with Miss D. Gandy (Mycology Department), and a paper describing the equipment and the first series of experiments has been published. A second series of experiments has been concerned with the effect of four ventilation rates (0·6, 1·8, 5·4 and 16·2 cu.ft. air/sq.ft. of bed/hr.), two levels of humidity (high and low) and two temperatures (65°F. and 70°F.) on fruiting. At both temperatures, with high humidity, increasing ventilation rate gave a greater number and weight of mushrooms per unit area of bed. An experiment at 65°F. and high humidity, with ventilation rates of 6, 9, 12 and 15 cu.ft./sq.ft./hr., gave an optimum at about 12 cu.ft./hr., but this result requires confirmation.

It is hoped to increase the number of chambers from eight to 16 during 1962 and to rehouse the unit. Preparatory work has been done to improve the design and, in particular, to improve air flow over the trays.

Causes of variability in mushroom experiments

An investigation into the causes of variability between plots receiving identical treatments has been continued jointly with D. Cooke of the Statistics Section (see also page 61). Results on the effect of spawning rates of practical value to growers are discussed in the special article on page 118 (in collaboration with D. Cooke).

Stage of picking

Further experiments (in collaboration with D. Cooke) on the effect of stage of picking on yield and flushing have confirmed the results reported in 1960. A relation has been established between the yield of untrimmed mushrooms and the stage of maturity at picking, using average weight per mushroom as an index of maturity. In investigating the adjustment required to untrimmed weights to give an estimate of marketable yield it was found that the ratio of pileus to stipe weight was approximately constant at 3:1 over the range from button to late flat. Beyond the late flat stage the ratio increase to 9:1 at the saucer stage. A more detailed investigation of the effect of stage of maturity at picking on the numbers of mushrooms produced and the periodicity of flushing is in progress.

Growth of mycelial strands

The growth and development of mycelial strands in the compost and casing layer has been studied further, and the results of the last three years' work are to be reported at the 1962 International Conference on Mushroom Science. Mycelium grew well in compost containing 63·8% water but poorly in the same compost containing 72·3% water. Growth in the wetter compost could be improved by reducing the density of packing and thus allowing better aeration. The formation of mycelial strands in the casing layer and the subsequent production of sporophore primordia does not depend on a well developed system of mycelial strands in the compost. Development of mycelial strands was better in a peat and chalk casing mixture containing 90·4% and 75% water than when the same casing mixture held only 13·2% water. Adding soluble salts to the casing mixture only had a slight effect on the formation of strands even when the casing had a *p*C value as low as 1·99.

Watering

Following work on the variability between plots, an attempt has been made to determine whether variability could be reduced by replacing normal hand watering at 2–3 day intervals with a method which would maintain the casing layer at a constant moisture level throughout cropping. So far, nylon felt wicks have been used to supply water from a reservoir to the casing layer. The wicks continuously supply water to the casing layer and obviate the alternate wetting and drying cycle inherent in hand watering.

The method is being examined as an experimental technique for the investigation of the water relations of the casing layer and for its possible commercial application.

Loamless composts (A. C. Bunt)

The work on loamless composts has been concentrated on the nutritional aspects of growth during the propagating stages of a range of plants including tomato, spinach, *Antirrhinum* and cucumber. Following previous work, a 3:1 volume mixture of sphagnum peat and fine sand was used throughout in a series of experiments designed to give information on the amounts of N, P, K, and Ca and Mg required in the base fertilizer. Three levels of each factor were applied using a 3^4 quasi-Latin square design giving 81 combinations of the treatments. This work has been repeated regularly over the year to provide information on seasonal effects and the interaction of nutrition with environment.

During the summer period plants grown in all mixtures were normal in habit and form. In the winter, however, there was a marked interaction between nitrogen, phosphorus and calcium. High levels of nitrogen and calcium in the presence of low phosphate caused abnormal growth. With the tomato this abnormal growth may take several forms ranging from epinastic curling of the leaves, high pigment, dieback on the lower leaves and loss of apical dominance to complete death of the young plant. Increasing the level of phosphate application materially reduces these troubles.

The incidence of these abnormalities increases with the onset of autumn and the progressive reduction in daylength and light intensity, and decreases in spring when the direction of change is reversed. Until the present work has gone further it is recommended that the nitrogen level should not exceed 3 oz. hoof and horn plus ½ oz. ammonium nitrate per bushel during the winter months. Calcium application should not exceed 4 oz. chalk plus 2 oz. dolomitic limestone, and phosphate application should not be less than 2 oz. superphosphate per bushel.

Work has been started to compare different sources of nitrogen, including hoof and horn, urea-formaldehyde, dried blood, urea, calcium nitrate, ammonium nitrate and ammonium

sulphate. There is a tendency for hoof and horn to give more trouble from abnormal growth compared with other nitrogen sources, and trouble is generally less from inorganic forms of nitrogen. Hoof and horn is becoming increasingly suspect as a source of trouble in loamless composts. The addition of micronutrients also reduces trouble from abnormalities. Boron appears to be the most important single element. The response to micronutrients is greatest where N and Ca are high and P low.

In the course of the work on loamless composts *Antirrhinum* has been widely used as a test plant. Difficulties in raising *Antirrhinum* seedlings in loam-based composts, when the loam fraction has been heat sterilised, are well known in commerce. The common symptoms of trouble are a non-pathogenic damping off of the seedlings, the cause being variously attributed to ammonia or sterilisation toxicities. A virtually trouble-free method of raising seedlings has been developed which is recommended for trial where growers meet this problem in loam composts. Seed is sown in the normal manner in a compost composed of a 1:1 (volume) mixture of peat and fine sand to which is added ½ oz. sulphate of ammonia, 1 oz. superphosphate and 4 oz. ground chalk or limestone per bushel. The method will not prevent damping off caused by fungi which should be guarded against by seed dressing or fungicide spraying.

Carnation: plant density and date of planting (G. F. Sheard and A. C. Bunt)

The combined plant density and date of planting trial started in July, 1960, has been continued, the final planting being made in March, 1961. The effect of the treatments on the cumulative yield and flower quality for the first six months' cropping for each date of planting is shown in Table I.

TABLE I

THE EFFECT OF PLANT SPACING AND DATE OF PLANTING ON THE QUANTITY AND QUALITY OF CARNATION BLOOM, VAR. 'WHITE SIM', FOR THE FIRST SIX MONTHS' CROPPING

Planting date	Spacing (*sq.in./plant*)	Cumulative yield (*blooms/sq.ft.*)					Remarks
		1st grade	*2nd grade*	*3rd grade*	Split	Total	
July 1960	21	7·7	11·3	4·9	3·1	27·0	Cropping: Nov. 1960–Apr. 1961
	35	7·9	8·0	2·6	3·1	21·6	
	49	8·9	5·8	1·6	2·3	18·6	
	63	9·2	4·8	1·1	1·7	16·8	
Sept. 1960	21	37·5	7·2	0·3	4·6	49·6	Cropping: April–Sept. 1961
	35	33·1	5·3	0·0	4·8	43·2	
	49	30·0	4·2	0·1	4·5	38·8	
	63	27·8	4·1	0·0	5·0	36·9	
Jan. 1961	21	33·4	9·1	0·3	1·0	43·8	Cropping: June–Nov. 1961
	35	29·0	5·0	0·0	0·4	34·4	
	49	25·6	4·9	0·0	0·9	31·4	
	63	23·2	4·6	0·0	1·1	28·9	
Mar. 1961	21	24·9	6·8	0·2	2·9	34·8	Cropping: July–Dec. 1961
	35	19·0	4·3	0·0	4·8	28·1	
	49	18·8	3·6	0·0	2·9	25·3	
	63	15·5	2·6	0·0	2·8	20·9	

Plant density had little effect on the numbers of blooms cut per unit area in the first two months of cropping of the July, 1960, and September, 1960, plantings, but the yield from the January, 1961, and March, 1961, plantings increased with increasing density, the difference between the highest density (7 in. x 3 in.) and the lowest density (7 in. x 9 in.) being 11 blooms per sq.ft. At the end of six months' cropping all treatments gave increasing production with increasing density. The time from planting to cropping varies with the planting date, and was four months for July planting, seven months for September, five months for January and four months for March. The total number of blooms cut to 31 August 1961 is shown in Table II.

TABLE II

CARNATION SPACING AND DATE OF PLANTING EXPERIMENT: TOTAL BLOOMS CUT *(PER SQ.FT. OF BED)* TO 31 AUGUST, 1961.

Planting date	Density (*sq.in./plant*)			
	21	35	49	63
7.7.1960	73 (*37*)	62 (*34*)	55 (*32*)	55 (*36*)
7.9.1960	45 (*34*)	38 (*30*)	35 (*28*)	34 (*25*)
6.1.1961	31 (*24*)	22 (*19*)	18 (*15*)	16 (*13*)
7.3.1961	23 (*18*)	18 (*13*)	15 (*11*)	11 (*9*)

Figures in brackets give number of blooms in Grades I & II

Chrysanthemum manurial trial (G. F. Sheard and A. C. Bunt in collaboration with G. W. Winsor and M. I. E. Long, Chemistry Dept.)

The manurial trial on early flowering chrysanthemums, variety 'Orange Sweetheart', completed its second season. Following the results of the 1960 trial the nitrogen levels were adjusted from 0, 7½ and 15 cwt./acre to 2, 6 and 18 cwt./acre nitro-chalk, phosphate levels from 0, 7½ and 15 cwt./acre to 0, 10 and 20 cwt./acre superphosphate, and potash from 0, 4 and 8 cwt./ acre to 0, 4 and 12 cwt./acre sulphate of potash. The application of dung was maintained at the same level as in 1960.

The treatments had a smaller effect on bloom size and stem length than in 1960. The largest effect was produced by the phosphate and potash treatments in advancing the median cutting date. This contrasted with the previous season when the main response was to nitrogen. Preliminary results of the main treatment effects for the 1960 and 1961 seasons are summarised in Table III and illustrate the possible large effects of seasonal variations in weather. (See, also, report of Chemistry Dept. on page 53).

TABLE III

THE MAIN FERTILIZER EFFECTS ON BLOOM SIZE, STEM LENGTH AND MEDIAN CUTTING DATE IN THE 1960 AND 1961 SEASONS WITH CHRYSANTHEMUM, VARIETY 'ORANGE SWEETHEART'

	1960			1961		
	Rate of fertiliser application			Rate of fertiliser application		
	0	1	2	0	1	2
Bloom size (*in.*)						
Dung	4·0	4·2	4·3	3·8	3·9	4·0
N	3·8	4·3	4·5	3·8	3·9	3·9
P	4·2	4·2	4·2	3·9	3·9	3·9
K	4·2	4·2	4·2	3·8	4·0	3·9
Stem length (*in.*)						
Dung	25·7	26·7	27·7	16·3	17·4	17·5
N	22·8	28·6	28·6	16·5	17·8	17·0
P	27·1	26·3	26·6	16·2	17·7	17·3
K	27·0	26·9	26·1	17·5	17·5	16·4
Median cutting (*days from first flower cut*)						
Dung	34·1	31·1	29·6	19·7	18·6	17·8
N	36·4	30·3	28·1	18·7	18·3	19·1
P	33·0	31·7	30·1	21·3	18·2	16·6
K	32·7	31·2	30·9	21·0	18·5	16·6

Keeping quality in cut flowers (G. F. Sheard)

Some preliminary work has been done on a problem of glasshouse roses known as "weak neck". The trouble is normally manifested when the flowers reach the florist or after final sale, resulting in a shortened life in water or in a floral arrangement. The symptoms show as a bending or collapsing of the stem immediately below the flower.

The weak neck is caused by a loss of turgidity due to failure of water uptake. The cause of the failure to take up water is seated in the base of the stem and seems more likely to be caused by physiological changes in the cut end than by blockage of the xylem by micro-organisms. Turgidity can be restored by the removal of a small piece of stem at the cut end and replacement of the stem in water. Dipping of the base of the stem in boiling water for 30 seconds also gave recovery, but was not so effective as cutting off the end of the stem. Removal of leaves does not reduce the trouble, but flowers tend to go over more quickly in sunlight and in moving air. There are marked differences in varietal susceptibility, the variety 'Poinsettia' being worst affected.

Rep. Glasshouse Crops Res. Inst. 1961 (1962), pp. 95–99

III. SPECIAL RESEARCH REPORTS

1. RESPONSE OF THE CUCUMBER PLANT TO DIFFERENT LEVELS OF ARTIFICIAL LEAF DAMAGE IN AN ATTEMPT TO SIMULATE THE EFFECTS OF RED SPIDER MITE

by

W. J. PARR and N. W. HUSSEY

The Red Spider Mite (*Tetranychus urticae* Koch) causes injury to plants principally by piercing the leaf tissue with its stylet-like mandibles to extract and feed on the cell contents. In heavy infestations the leaves become covered with these feeding punctures, and there is considerable loss of chlorophyll and subsequent necrosis.

In a previous experiment the effect of different mite populations on the cropping of cucumbers was studied (Hussey and Parr, *in preparation*). They showed that the plants could sustain a certain level of mite damage without loss in yield, but severe damage caused by an uncontrolled infestation could reduce the crop by as much as 36%. Such reductions were caused by decreases in the number of fruits formed rather than by differences in the weight of individual fruits.

The present paper describes the effect of different levels of artificial leaf damage on fruit production.

Method

Twenty plants (*var.* 'Butcher's Disease Resister'), from seed sown on 16 June, were set out in beds on 10 July in four blocks, each comprising five randomised treatments. To prevent the foliage of adjacent plants overlapping they were spaced 5 ft. apart along one side of a 100 ft. cucumber house. Lateral shoots below the first wire (2 ft. high) were removed, and thereafter the growth of each plant was restricted to nine laterals on each side of the main stem, each bearing two sub-laterals.

Mite damage was simulated by frequent removal of a proportion of the leaf tissue to establish two levels of damage corresponding to 25% and 50% of the total leaf area of the control plants. These levels were maintained by periodically assessing the total leaf area of both treated and untreated plants. The treatments, which differed in time of initiation and duration, covered three periods (Table I), period A being 3 July–21 August, period B 21 August–28 September, and period AB 3 July to 28 September.

TABLE I

SCHEDULE OF ARTIFICIAL LEAF DAMAGE TREATMENTS
(PLANTED: 10 JULY)

Treatment code	Leaf-area removed (%)	Date treatment:—	
		Initiated	Ceased
0	0	—	—
50B	50%	21 August	28 September
25AB	25%	3 July	„
50AB	50%	„	„
50A	50%	„	21 August

The main stem was stopped on 21 August after the ninth pair of laterals had developed. Each cucumber was labelled as soon as it appeared and its development, weight and position on the plant recorded . All fruits forming on the main stem were removed.

Cucumber mildew was controlled by repeated sprayings with Karathane.

Results

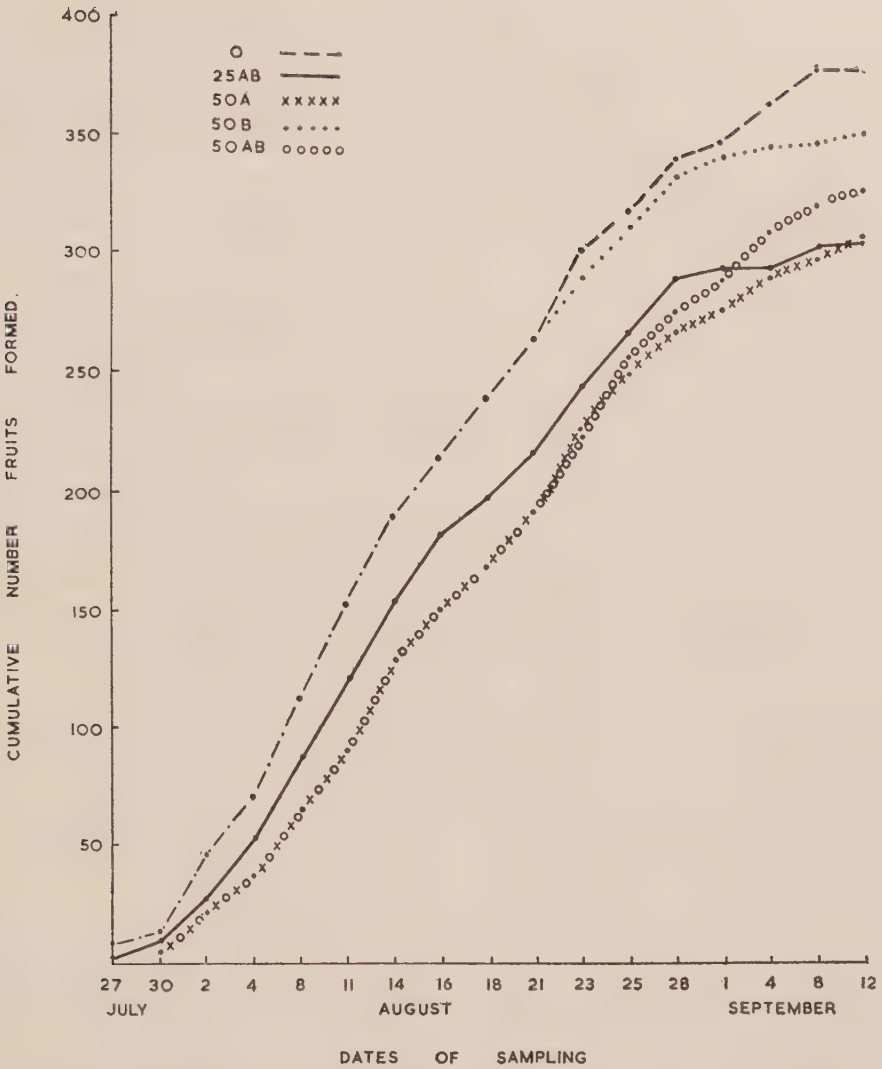
There was a considerable decrease in the number of fruits formed at all damage levels (Table II). During the first four weeks after fruit formation began, when both the 0 and 50B plots were untreated, each plant produced an average of 66 fruits whereas the 50AB and 50A plots produced only 48 fruits per plant. Also, the plants were noticeably retarded in growth for two weeks after planting and the first fruits formed three days later than those on the control plants. Growth of plants in the 25AB plots was unaffected, but the number of fruits formed fell to 54 per plant.

TABLE II

EFFECT OF LEAF-DAMAGE ON FRUIT FORMATION

Treatment	Number of fruits formed		
	27 July to 21 August	22 August to 12 September	Total
0	287	113	400
50B	240	86	326
25AB	216	89	305
50AB	189	135	324
50A	193	115	308

The accompanying Figure shows the cumulative number of newly-formed fruits at each sampling. For clarity, the fruit formation on some plots has been meaned for the period during which they were being treated in the same way; thereafter, the respective increments have been separated. The figure shows that during the first four-week period the plants receiving 25% and 50% damage took about three and six days longer respectively than the undamaged plants to form the same number of fruits. Reducing the leaf area of the 50B plots to 50% of that on the controls, six weeks after planting, did not markedly decrease the numbers of fruits formed for at least ten days after treatment. Although the 50% damage level ceased on the 50A plots at the same time, the plants failed to respond to the extra growth and no increase in fruit production was recorded. Any long-term effects of these later treatments were obscured by the general decline in fruit production which occurred on most of the experimental plots during September.



Cumulative total of cucumber fruits forming on plants subjected to different degrees of artificial defoliation.

An unexpected feature of the results was the high level of fruit production maintained by the 50AB plots during the last three-week period. Despite the 50% damage maintained throughout the experiment the total number of fruits formed subsequently exceeded that of both the 25AB and 50A treatments (see Figure).

The proportion of fruits maturing in all treatments was about the same (Table III). The marked decline in the proportion harvested from fruits formed during the last three-week period was probably due to the very restricted growth and also to a severe attack by the leaf fungus *Trichothecium roseum*. Under more normal conditions of cucumber culture it is the practice to allow a much freer development of lateral growth than was possible here. This would have stimulated the plants to mature a greater proportion of fruits and would have minimised the effects of the fungus.

TABLE III

SUMMARY OF CROP YIELD

Treatment	Fruits matured from fruits formed (%)		Mean development time (*days*)	Mean weight of fruits (*oz.*)
	27 July to 21 August	22 August to 12 September		
0	33·9	12·1	24·7	15·1
50B	35·7	11·5	26·4	13·8
25AB	41·5	15·6	26·0	14·0
50AB	35·0	14·8	26·3	13·1
50A	34·5	13·9	24·5	14·9

While the number of fruits formed did not differ appreciably between laterals, the proportion of mature fruits picked showed a progressive decline from the fifth lateral upwards (Table IV).

TABLE IV

FRUIT PRODUCTION ON LATERAL GROWTH

Lateral	First fruits formed	Total fruits formed	Fruits matured (%)
1	27 July	159	35·2
2	30 July	163	42·9
3	2 August	172	37·2
4	4 August	132	33·3
5	11 August	140	28·6
6	14 August	169	26·6
7	16 August	165	30·6
8	21 August	139	20·9
9	21 August	166	12·0

A comparison of the average weight of individual fruits (Table III) showed that those from plants maintained throughout at the 25% and 50% damage level were 1 oz. and 2 oz. less, respectively, than those from the untreated plants.

The small differences in development time between fruits maturing in each treatment were not significant (Table III). The minimum period from planting to initiation of the first fruits was 17 days, while the average period from initiation to picking of 430 fruits was 25 days.

Discussion

The results largely confirm the previous work with mites that loss of photosynthetic area due to extensive leaf damage decreases fruit formation. Gregory (1916) reported that when vegetative growth of cucumbers (as measured by increments in axillary shoots) was compared with crop records, periods of high vegetative activity were associated 27–28 days later with large yields of fruit. The present experiment suggests that the application of damage will reduce the numbers of fruits forming ten days later and hence the weight of the crop after a further 25 days. Presumably the high vegetative activity referred to by Gregory must have been stimulated by suitable conditions at some earlier time. If fruit formation is not affected for ten days it is reasonable to assume that vegetative growth would be affected within a shorter

period. If this period were seven days, then the two studies would give identical periods between the application of damage and crop reduction.

The low yield of mature fruits was partly attributable to the limited growth of the plants resulting in a gradual accumulation of ageing foliage with subsequent loss in vigour and ability to complete fruit development.

It is evident that in future studies utilising artificial damage it will be necessary to allow much more freedom of growth to maintain maximum fruit formation and yield.

SUMMARY

Removal of up to 50% of the leaf-area of cucumber plants decreased the number of fruits formed by as much as 25%. The interval between leaf damage and reduction in yield of mature fruits was 35 days.

REFERENCES

1. Gregory, F. G. (1916). Physiological conditions in cucumber houses. *Rep. exp. Res. Sta. Cheshunt, 1916*, 10.
2. Hussey, N. W. & Parr, W. J. The effect of Glasshouse Red Spider Mite (*Tetranychus urticae* Koch) on the yield of cucumbers. (*In preparation*).

Rep. Glasshouse Crops Res. Inst. 1961 (1962), pp. 100–102

2. THE ATTENUATION OF CARNATION MOTTLE VIRUS IN PLANTS

by

M. HOLLINGS and OLWEN M. STONE

Heat treatment is widely used to free many kinds of plants from certain viruses, thus providing a small basic stock from which a large working stock is then propagated. Rigorous testing of the foundation plants is obviously essential, and success or failure depends on the reliability of the testing method.

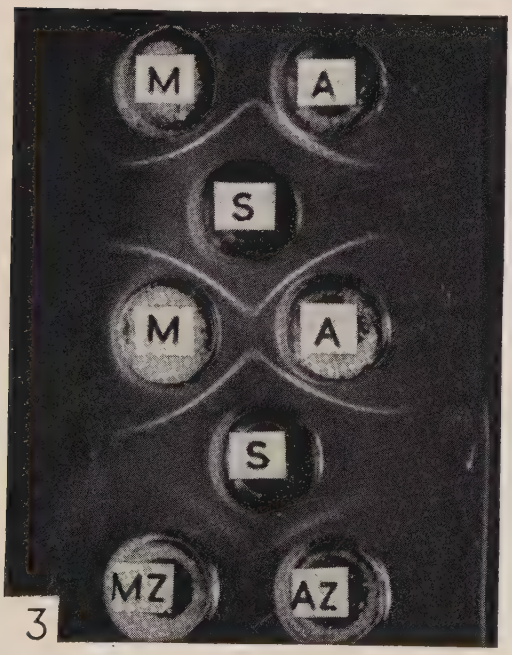
Inoculation of sap from young leaves of carnations infected with mottle virus normally produces up to 1,000 lesions per leaf in *Chenopodium amaranticolor* Coste & Reyn., and the virus can be detected in sap diluted to more than 1/50,000. These lesions develop in four to seven days, and are nearly all small, yellow-green dots less than 1 mm. in diameter (Plate 1). About 1% of the lesions are necrotic brown dots with a pale central speck, and further inoculations to *C. amaranticolor* from such lesions induce numerous, typical chlorotic lesions, together with a higher proportion than normal of the necrotic type. This test has proved thoroughly reliable under ordinary circumstances.

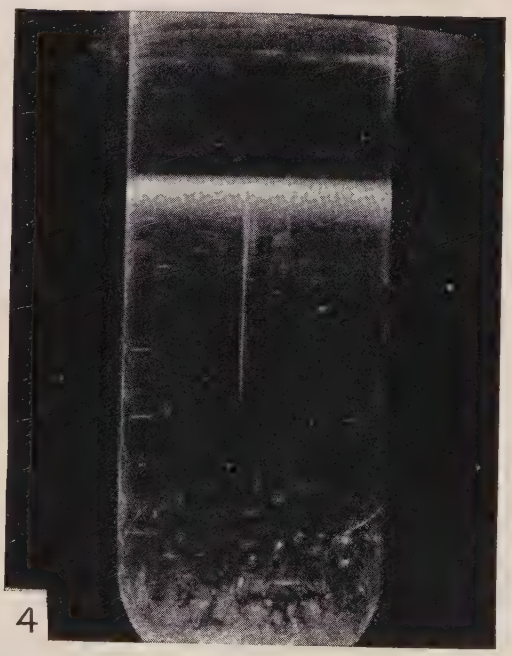
We have confirmed the findings of Kassanis (1955) that mottle virus is not eliminated from carnations grown at 38°C. for four weeks; nor from small cuttings (2–4 cm. long) taken immediately after heat treatment.

As part of the programme to obtain virus-free clones of carnation, tips 0·25–1 mm. long were excised from the shoots of carnation plants that had been kept at 38°C. for four weeks, and grown in tubes of sterile nutrient. About 15% of tips survived to become plants, which were tested at approximately two-monthly intervals by inoculation to *C. amaranticolor*. Some of them induced numerous chlorotic lesions, typical of mottle, after four to seven days, and were discarded. Others, that gave no lesions in several tests, are provisionally considered to be virus free. However, some plants of the varieties 'Joker', 'Pink Shibuiya' and 'Orchid Beauty' gave very few, chlorotic spots on the older inoculated leaves of *C. amaranticolor* after 21 days; these spots expanded to red-rimmed lesions 2–4 mm. in diameter during the next two weeks (Plate 2). This reaction was entirely different from that of mottle virus, both in the size of lesion and in the latent period. The reaction was not merely due to low virus concentration because typical mottle virus, diluted 1/50,000 or 1/100,000, gave several local lesions of typical mottle form after about six days; within a further 18 days one or two fresh lesions of abnormal type had appeared on some inoculated leaves.

When abnormal lesions in *C. amaranticolor*, derived either from tip cultured carnations or from greatly diluted inocula, were cut out and inoculated to other *C. amaranticolor* plants, numerous chlorotic local lesions, indistinguishable from those caused by mottle virus, developed in four to seven days. Purification of the virus by the butanol-centrifugation method from these leaves gave preparations which reacted specifically with mottle antiserum in precipitin tube and gel-diffusion tests, and produced a zone characteristic of mottle virus in density gradient centrifugation (Plates 3 & 4).

Typical mottle virus has been regularly isolated by direct inoculation to *C. amaranticolor* from excised tips of non heat-treated carnations, and "attenuated" mottle occasionally detected in some tips less than 0·4 mm. in length. Many tips of this size, however, contained typical mottle virus which would obscure any lesions of "attenuated" type.





1. Local chlorotic dots of typical carnation mottle virus in *Chenopodium amaranticolor*, six days after inoculation. 2. Local lesions of "attenuated" type, 24 days after inoculation. 3. Gel-diffusion slide showing serological relationship between typical carnation mottle virus (M) and "attenuated" mottle (A). Carnation mottle antiserum in wells (S). Wells (MZ) and (AZ) contain extracted zone from density gradient centrifugation with typical mottle and "attenuated" virus respectively. 4. Specific zone in density gradient centrifugation column of "attenuated" mottle virus.

(To face page 100

"Attenuated" lesions were also obtained by inoculating *C. amaranticolor* with sap from *Lychnis chalcedonica* L. and *Saponaria officinalis* L. infected by grafting with scions of carnation, *var.* 'Joker', containing mottle virus. These lesions produced typical mottle lesions on sub-culture to other plants of *C. amaranticolor*, and purified preparations from the latter were serologically indistinguishable from the original isolate of mottle virus in 'Joker' carnation. Although infected by grafting, *L. chalcedonica* and *S. officinalis* were not infected by mechanical inoculation with preparations of mottle virus that had been purified to avoid the inhibitory effects of carnation sap.

The similarity in reaction between inoculations to *C. amaranticolor* from these two species, both resistant to infection with mottle virus, and from excised carnation tips or plants grown from them, could be based upon similar mechanisms. These might inactivate the virus, or confine its production to a form unable to multiply normally in carnation. When carnation shoots that had consistently given only the "attenuated" type of lesions over some months were processed by the butanol-centrifugation method the final pellets were much smaller than those normally obtained. These preparations gave no serological reaction with mottle antiserum, no visible zones in density gradient centrifugation, and only very few lesions, of "attenuated" type. in *C. amaranticolor.*

Density gradient or serological tests detected normal mottle virus in similar preparations from about 80 mg. of carnation leaf tissue, and infectivity tests in less than 1 mg. of tissue, often from the meristem dome itself. Moreover, preparations rendered non-infective by ultra-violet radiation, or the addition for formol to 0·2%, still produced the characteristic zones in density gradient tests, and serological activity was unimpaired. Thus there was no evidence for the accumulation in carnations containing "attenuated" mottle virus of particles that lacked infectivity but could be detected in other ways. Rather the evidence favoured a mechanism that reduced the virus concentration to a very low level, as well as altering its behaviour when transferred to another plant.

Changes in virulence have been reported for sugar beet curly top virus; the virulence towards sugar beet was reduced by passage of the virus through *Chenopodium murale* (Carsner, 1925). The alteration persisted until the virus was passaged through *Stellaria media*, after which its virulence to beet was restored (Lackey, 1932). Bawden (1956, 1958) recorded host-induced changes that were reversible in tobacco mosaic virus, and Cadman and Harrison (1959) described multiplying and non-multiplying types of particle of tobacco rattle virus.

Mottle virus survived dilution, heating in sap, and heat treatment in the growing plant, better in the form that gave "attenuated" lesions than in the typical condition. This might represent the selection of a more resistant type of virus particle which multiplies less readily without transfer to another host, or a reversible change in the pattern of virus multiplication. This latter is supported by the immediate restoration of normal virulence and characteristics of carnation mottle on transfer of "attenuated" virus through *C. amaranticolor.* Our data do not indicate the nature of the mechanism, nor is it yet known whether "attenuated" mottle virus spreads as readily from carnation to carnation by handling and contact as does normal mottle virus.

These results emphasise the need for thorough and repeated testing of any carnations derived from meristems before they are claimed to be "virus free." At least 21 days must be allowed for symptoms to develop in *C. amaranticolor* plants used for indexing, instead of the usual 7–10 days.

REFERENCES

1. Bawden, F. C. (1956). Reversible, host-induced changes in a strain of tobacco mosaic virus. *Nature, Lond.*, **177,** 302–4.
2. Bawden, F. C. (1958). Reversible changes in strains of tobacco mosaic virus from leguminous plants. *J. gen. Microbiol.*, **18,** 751–66.
3. Cadman, C. H. & Harrison, B. D. (1959). Studies on the properties of soil-borne viruses of the tobacco-rattle type occurring in Scotland. *Ann. appl. Biol.*, **47,** 542–56.
4. Carsner, E. (1925). Attenuation of the virus of sugar beet curly-top. *Phytopath.*, **15,** 745–57.
5. Kassanis, B. (1955). Some properties of four viruses isolated from carnation plants. *Ann. appl. Biol.*, **43,** 103–13.
6. Lackey, C. F. (1932). Restoration of virulence of attenuated curly-top virus by passage through *Stellaria media*. *J. agric. Res.*, **44,** 755–65.

Rep. Glasshouse Crops Res. Inst. 1961 (1962), pp. 103–108

3. DIE-BACK OF MUSHROOMS: A DISEASE ASSOCIATED WITH A VIRUS

by

DOREEN G. GANDY and M. HOLLINGS

Symptoms of a group of mushroom disorders of uncertain origin and variously named La France disease, Mummy disease, Watery Stipe, Brown disease and X-disease include the progressive deterioration of mycelium, much reduced cropping, death of sporophores before reaching maturity, waterlogging of tissues especially those of the stipe and various sporophore abnormalities, of which one of the commonest is an elongation of the stipe and the production of a small rounded pileus ("drumstick") (Gandy, 1958, 1960a, b, c; Kowalesky, 1961; Lambert, 1961; Sinden & Hauser, 1950; Storey, 1958; Storey & Lester, 1959; Tucker & Routien, 1942).

Discrepancies in the reports of different outbreaks may have resulted from variations in the development of the same disease or because different disorders were involved. Changes in the chemical and physical composition of the composts, resulting from the introduction of stiff straw varieties of wheat, were suggested as a possible cause of many poor crops. Storey & Lester (1959) collected data which indicated that some crop failures were primarily related to an unfavourable environment, particularly high relative humidity and insufficient ventilation. Waterlogged stipes also appeared under similar conditions in some of the controlled environment experiments done by Flegg & Gandy at this Institute (unpublished) in crops which gave average yields. Whilst watery stipes can develop in an adverse environment, a transmissible factor can be associated with these symptoms (Gandy, 1960b, c, d). They developed when compost and mycelium, obtained from badly affected crops, was inoculated into experimental plots. The severity of attack depended upon the time of inoculation, being greatest at spawning and least when the mycelium had fully colonised the compost (Gandy, 1960c). Storey & Lester (1959) found that inoculating plots about to come into production had no effect unless large amounts of inocula were used, when numbers of mushrooms were greatly reduced.

In the earlier stages of the transmissible disease, the mycelium in the compost still appears healthy, but when sub-cultured on malt agar it grows slowly, forming an adpressed colony, pale buff in colour and without the usual development of coarse strands. As the disease progresses, the finer mycelium dies back and disappears from the compost and the remaining strands cannot be regenerated on agar. It is these unusual cultural characteristics which distinguish the transmissible disease from those caused by other factors. To identify this transmissible disease the name "Mushroom Die-back" is suggested.

Transmission of die-back was demonstrated in "pure culture" *in vitro* (Gandy, 1960b, c, d) (Plate 5). The cultures used were white strains of mushroom; a brown strain similarly tested was not affected. Merek (1960) also found differences in susceptibility of mushroom strains to Mummy disease.

Although single spore isolations from healthy white sporophores vary considerably and may bear superficial resemblances to diseased colonies, the variations cannot be transmitted to test cultures, an essential difference from die-back.

Because the transmissible nature of die-back indicated that a virus may be involved, the effect of temperature was studied. Diseased cultures in Petri dishes were grown at 33°C. for two weeks, then peripheral hyphae were transferred to fresh medium and kept at 25°C. The new cultures produced apparently healthy growth, which was confirmed by transmission test. Peripheral tips similarly transferred from cultures maintained at 25°C. continued to grow abnormally (Gandy, 1960b, c).

Transmission of die-back was demonstrated *in vitro* only when the inoculum contained viable abnormal cells; attempts to obtain a preparation in which all the cells had been ruptured mechanically proved impossible. An alternative method, used by Martin (1952) in the purification of dahlia mosaic virus, involved the treatment of mycelial suspensions with potassium cyanide solution. It was hoped that this would kill the cells without inactivating any virus present. A stronger solution (1%) than that originally recommended (0·3%) was required to kill the mycelium, and mycelium killed in this way failed to transmit the abnormality, as had also hyphae killed by heat. Sometimes, however, mycelium treated with weaker solutions produced apparently healthy growth.

Virus purification

First attempts to extract a possible virus by differential centrifugation were done from mycelium grown in a liquid medium. They failed, possibly because so little material was available. Later, purification experiments were done with sporophores from disease outbreaks on mushroom farms, confirmed by mycelial isolations and transmission tests.

Fresh sporophores from infected and healthy crops were processed by the butanol-centrifugation method of Tomlinson, Shepherd and Walker (1959). Batches (62 g.) of sporophores were minced with 78 ml. of M/20 phosphate buffer, *p*H 7·6, containing 0·1% thioglycollic acid. The mixture was shaken whilst *n*-butanol was added drop by drop to 8·5% of the total volume, then clarified by centrifugation for 25 min. at 12,500 r.p.m. in the R.30 rotor of a Spinco Preparative Ultracentrifuge. The supernatant fluid was filtered, then centrifuged for 120 min. at 30,000 r.p.m. in the R.30 rotor. The pellets obtained were pale fawn and translucent: those from infected material were much larger (8–12 mm. diameter) than those from the healthy (6–10 mm.). Pellets were re-suspended in 1/20th original wt.vol. of M/30 phosphate buffer and insoluble matter removed by brief centrifugation under aseptic conditions. The highly opalescent supernatant fluid thus obtained is referred to as the "soluble fraction" of the purified preparations, and the insoluble sediment as the "insoluble fraction." The "soluble fraction" was then tested for infectivity, and for the production of visible zones in density gradient centrifugation.

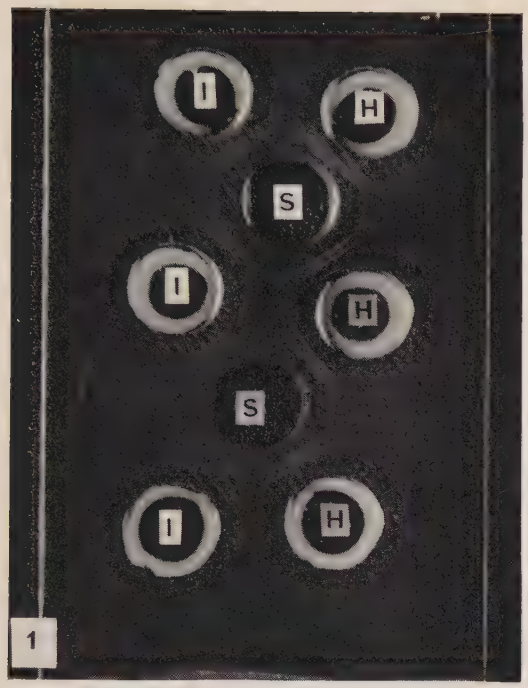
(*a*) *Infectivity tests*

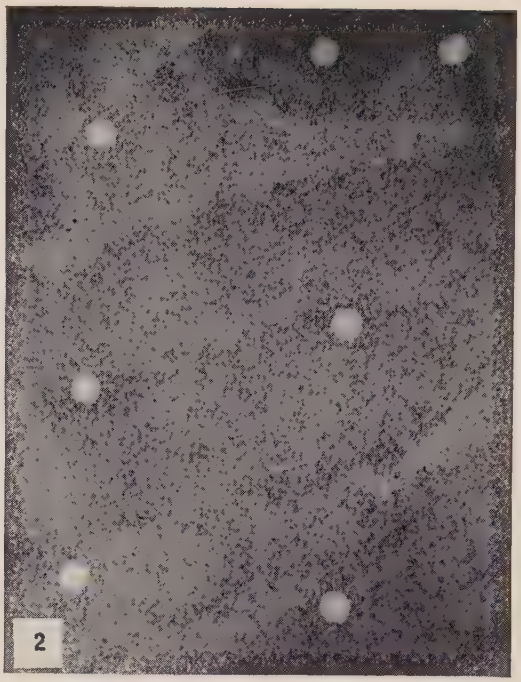
Discs cut from healthy cultures growing on 2½% malt agar were soaked in the test liquid for 30 min., then plated out on fresh medium. Some of the preparations were bacteriologically sterile, but with others bacterial contamination severely inhibited mycelial growth and, despite sub-culture, invalidated the tests. No definite transmission could be demonstrated.

(*b*) *Density gradient centrifugation*

When purified preparations of some viruses are centrifuged in tubes containing gradient columns of sucrose solutions, they produce light-scattering zones, visible when suitably illuminated from above, at characteristic levels in the tubes.

One-ml. aliquots of the "soluble fraction" were layered on top of sucrose gradient columns (5 ml. each of 10, 20, 30 and 40%, and 10 ml. of 50% sucrose in M/30 phosphate buffer, *p*H 7·6) and sedimented for 120 min. at 25,000 r.p.m. in the Spinco R.25 rotor. Both healthy and diseased material gave intense, creamy white zones in the region of the 10–22% sucrose concentrations. The preparations from infected sporophores, however, produced an additional, sharply defined zone, of the blue-grey colour produced by many plant virus preparations, in the 28–30% sucrose levels; immediately below this zone a more diffuse, greyish layer extended down to the 36% sucrose level (Plates 3, 4). The visible zones were extracted by hypodermic needle pushed through the wall of the tube while the latter was strongly illuminated from above. As





1. Serological reactions in gel-diffusion slide: wells 'S' contain antiserum against preparations from infected sporophores: wells 'I' contain purified preparation from infected sporophores; wells 'H' similar preparations from healthy sporophores. Similar antigens are present in both healthy and infected material. 2. "Spherical" particles present in electron microgram of purified preparations from die-back sporophores. Particle diameter approximately 25 mμ. 3. 4. Light-scattering zones visible in sucrose columns after density gradient centrifugation of preparations from healthy (3) and die-back (4) sporophores. The specific zone containing virus particles is indicated at 'Z'.

control, samples were taken from the corresponding levels in tubes containing the healthy preparations. The zones were tested for infectivity by the method described above, and samples were kindly examined under the electron microscope by Mr. H. L. Nixon at Rothamsted Experimental Station. A few virus-like "spherical" particles, approximately 25 mμ in diameter, were found in both the "soluble fraction" of the purified preparation and the zone at 28% sucrose level from the diseased material, but no particles were seen in samples prepared from healthy sporophores (Plate 2).

After 24 hr. or more at −20°C., purified preparations from diseased material no longer gave the characteristic zone at 28–30% sucrose level, but the more intense upper zone, common to both diseased and healthy preparations, was still found. Similarly, purified preparations of some plant viruses which gave characteristic zones when freshly prepared no longer did so after storage at −20°C.

Preparations were made from infected and healthy sporophores by the phenol-water extraction method of Schlegel (1960), followed by ultra-centrifugation. As expected, the preparations gave no light-scattering zones when centrifuged in density gradient columns of sucrose. They were not infective, as persistent traces of phenol in the extracts were toxic to test cultures.

Serological reactions

Because many plant virus preparations that produce characteristic visible zones after density gradient centrifugation have proved satisfactory antigens (Hollings & Stone, unpublished), an attempt was made to obtain an antiserum to die-back by injecting preparations from infected mushrooms into rabbits.

Sporophores from two widely separated localities were processed by the butanol-centrifugation method and the final pellets re-suspended in 1/75th original wt./vol. of M/30 phosphate buffer. One-ml. aliquots of the "soluble fraction" were emulsified with an equal volume of Freund's Complete Adjuvant (Bacto) and injected intramuscularly into rabbits. Two injections were given, two weeks apart, and serum obtained three weeks after the second injection. One serum was made with antigen preparations treated with formol to 0·2% before injection, the other had none. This use of formol had enabled an antiserum to be prepared against celery yellow vein virus (Hollings & Stone, 1962), for untreated virus preparations had been non-antigenic in rabbits. With mushroom die-back, however, there was no noticeable difference between antisera to treated and untreated preparations.

The sera were tested against the homologous antigens in precipitin tube and gel-diffusion slide tests. Using sera diluted 1/10, reactions occurred with dilutions of sporophore preparations up to 1/64, giving a precipitate of the somatic type characteristic of isodiametric antigens. However, the sera reacted equally well with comparable preparations of both infected and healthy material: in gel-diffusion tests the conspicuous double reaction lines formed with diseased preparations were identical and continuous with those of healthy preparations, and both soluble and insoluble fractions gave these lines. In addition, a very faint line was visible just outside the antigen well with the soluble fraction only of some diseased preparations. Although this reaction may be specific, it is wholly unreliable as a test at present (Plate 1). There was no reaction between normal serum and either healthy or diseased mushroom preparations. In further gel-diffusion tests with extracted zones formed in density gradient centrifugation the top zone gave the complete serological reaction and no antigens were detected below this level.

Infectivity tests with growing mushrooms

The total purified preparation (i.e., soluble plus insoluble fractions) from diseased mushrooms was inoculated into four trays (each 6 sq.ft.) bearing a first flush of healthy mushrooms.

Inoculation was by a combination of injection of the bases of sporophores and application of the liquid inoculum to the casing and compost in which the mycelium was growing. Each tray received 2 ml. of preparation, and two preparations were used. The sporophores produced in subsequent flushes appeared normal (*cf.* Infectivity and rate of spread experiments). Mycelium was isolated from these and from control plots four, six and nine weeks after inoculation. All isolates from one tray produced on agar growth typical of die-back. Double inoculations of Petri dishes with these isolates and healthy test culture showed clearly the transmission of the abnormality, and its spread through the test colony. Anastomoses were observed between hyphae of the healthy and die-back cultures (Plate 6). Isolations from a second tray, nine weeks after inoculation with another preparation, also produced a die-back culture.

Discussion

One of the main difficulties in this work has been to obtain enough infected material for processing by the virus purification methods available; diseased mycelium grows extremely slowly in culture, sporophores are characteristically few and often die prematurely. Only occasionally have the necessary quantities of suitable sporophores been available. Moreover, absolutely fresh material is essential, because we failed to detect any virus in sporophores that had been stored for a few days at −20°C. The few particles in electron micrograms indicated that, even in fresh preparations, the virus was present in very low concentration compared with many plant viruses.

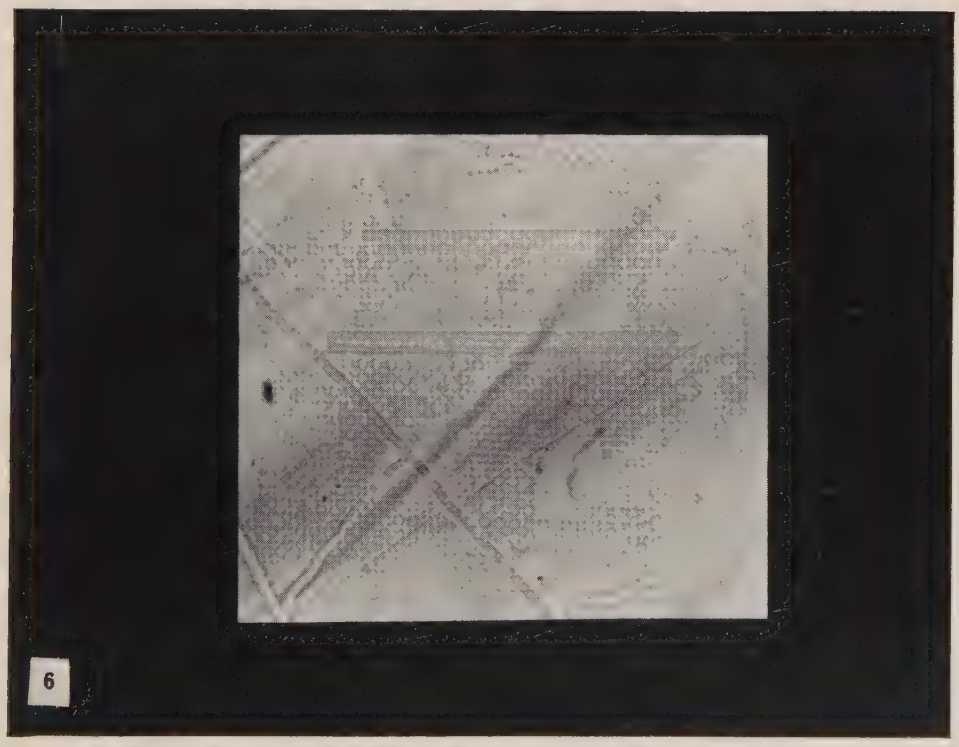
Low virus concentration, and the difficulty of introducing virus preparations into mushroom cells without excessive damage, may account for our failure to infect mycelial cultures *in vitro* with cell-free virus preparations. However, we have transmitted the disease by inoculating sporophores with cell-free preparations containing virus: mycelium isolated from inoculated trays produced, on agar medium, the abnormal growth characteristic of die-back, and this could be further transmitted *in vitro* to healthy cultures (Plate 5). Owing to unserviceability of the ultracentrifuge it was not possible to do density gradient tests with the sporophores from the first tray to show growth abnormality in pure culture, and by the time it was manifest in the second case cropping had already ceased.

A disease of *Helminthosporium victoriae* which has many similarities with die-back was described by Lindberg (1959). This could be transmitted by hyphal anastomoses between healthy and diseased mycelium, which is a form of graft transmission, and also by a cell-free preparation obtained from diseased mycelium. Lindberg considered that the causal agent was virus-like, although the cell-free preparations were not examined under an electron microscope.

Jinks (1959) described "vegetative death" in *Aspergillus glaucus* which also has similarities to die-back, but he considered that it was caused by lethal suppressive cytoplasms. Bawden & Gregory (1952) found nothing in mushrooms with "mummy disease" to suggest a virus as the cause.

It is difficult to assess accurately the extent to which the mycelial degeneration is responsible for sporophore abnormalities. It is common to find them whenever the substrate is unfavourable and the mycelium is struggling, e.g. in bad compost. This condition must also occur when the fine strands of the mycelial system are disappearing yet the system as a whole is still capable of producing sporophores. Disruption of the translocation system would also account for the death of sporophores. Unfavourable atmospheric conditions can cause sporophore abnormalities, but there is no accompanying mycelial degeneration.

The relationship between die-back and other diseases of the same type can only be a matter for speculation. Many of the descriptions of these diseases are inadequate and in no



5. Mycelial cultures isolated from mushroom trays inoculated with purified virus preparation: from infected tray (right), showing reduced growth and habit typicalof die-back cultures; from healthy control tray (left).
6. Anastomoses between hyphae in Petri dish culture.

(To face page 106

case was any causal agent discovered. We cannot avoid adding another name to the list: die-back refers to a consistent symptom in commercial crops, viz. the degeneration of the mycelium. The infectivity test in pure culture from the isolated mycelium provides the only reliable method of diagnosis. We have been unable to demonstrate that the virus present is antigenic, and any specific serological reaction would tend to be obscured by the powerful antigens present in both infected and healthy mushrooms.

SUMMARY

Die-back is a mushroom disease characterised by an abnormal condition of the mycelium which can be transmitted through hyphal anastomoses.

Sporophores associated with this condition were examined and virus-like "spherical" particles were found.

Healthy mushroom beds were inoculated with preparations containing these particles and the transmissible mycelial abnormality was produced.

REFERENCES

1. Bawden, F. C. & Gregory, P. H. (1952). In Report of Plant Pathology Department, *Rep. Rothamsted exp. Sta. 1951*, 84–5.
2. Gandy, D. G. (1958). *Rep. Glasshouse Crops Res. Inst., 1957*, 129–33.
3. Gandy, D. G. (1960a). *Rep. Glasshouse Crops Res. Inst., 1959*, 62–4.
4. Gandy, D. G. (1960b). Watery stipe of cultivated mushrooms. *Nature*, **185,** 482–3.
5. Gandy, D. G. (1960c). A transmissible disease of cultivated mushrooms (Watery stipe). *Ann. appl. Biol.*, **48,** 427–30.
6. Gandy, D. G. (1960d). Progress with Watery stipe. *MGA Bull.*, **127,** 247–51.
7. Hollings, M. & Stone, O. M. (1962). Use of formalin-treated antigen in the production of antiserum to a plant virus. *Nature*, **194,** 607.
8. Jinks, J. L. (1959). Lethal suppressive cytoplasms in aged clones of *Aspergillus glaucus*. *J. gen. Microbiol.*, **21,** 397–409.
9. Kowalewski, T. R. (1961). Observations on X-disease. *A.M.I. Mushroom News.*, **9,** 3–4.
10. Lambert, E. R. (1961). Progress report on X-disease. *A.M.I. Mushroom News*, **9,** 4–7.
11. Lindberg, G. D. (1959). A transmissible disease of *Helminthosporium victoriae*. *Phytopath.*, **49,** 29–32.
12. Martin, C. (1952). Améliorations apportées a l'extraction du virus de la mosaique du dahlia (*Marmor dahliae*) Holmes. *Ann. Inst. nat. Rech. agron.* (*Ann. Epiphyt.*) **3,** 395–6.
13. Merek, E. L. (1960). A Study of the mummy disease of the cultivated mushroom *Agaricus campestris* L. ex Fries. Abstr. in *Dissertation Abstracts*, **21,** no. 7, 1961.
14. Schlegel, D. E. (1960). Transmission of several plant viruses by phenol-water extracts of diseased tissues. *Phytopath.*, **50,** 156.
15. Sinden, J. W. & Hauser, E. (1950). Report on two new mushroom diseases. *Mushroom Science*, **1,** 96–100.

16. Storey, I. F. (1958). What is brown disease? *MGA Bull.*, **100,** 185–91.

17. Storey, I. F. & Lester, E. (1959). Watery stipe disorder of mushrooms. *Mushroom Science*, **4,** 430–41.

18. Tomlinson, J. A., Shepherd, R. J. & Walker, J. C. (1959). Purification, properties and serology of cucumber mosaic virus. *Phytopath.*, **49,** 293–9.

19. Tucker, C. M. & Routien, J. B. (1942). The mummy disease of the cultivated mushroom. *Res. Bull. Mo. agric. Exp. Sta., 358.*

Rep. Glasshouse Crops Res. Inst. 1961 (1962), pp. 109–117

4. THE RELATIONS BETWEEN DAYLENGTH AND THE GROWTH OF THE FRUIT OF THE TOMATO

by

A. J. COOPER

Preliminary observations on seasonal patterns of development in the tomato have already been published (1, 2, 3, 4, 5, 6, 7, 8). During 1961 the work that was begun in 1959 to obtain detailed information on the relations between tomato development and daylength was completed. Fifty-six sowings of the 'Potentate' variety were made at weekly intervals, beginning on 22 September 1959 and ending on 11 October 1960. Within a few days of germination four seedlings of identical height and cotyledon length were selected and planted directly into the border soil of a glasshouse in rows 3 ft. apart and with a spacing of 3 ft. between the plants in the rows. It is emphasised that the plants were thus never subjected to any form of root restriction, such as would be imposed by a pot. The planting positions for each of the plants in each of the sowings was completely randomised. The effect of changes in temperature was minimised by maintaining the night temperature at 60°F. and the day temperature as close to 70°F. as external conditions allowed.

Measurements of the diameter of each fruit were made at weekly intervals. The cube of the radius was used as an estimate of the volume of each fruit, and is so used throughout this report. As an estimate of the weekly rate of fruit volume production the following equation was used:—

$$P = (a_2 + b_2) - (a_1 + b_1)$$

where P = the weekly rate of fruit swelling

a = the fruit volume present on the plant

b = the accumulated total of fruit volume picked

1 = first week under consideration

2 = second week under consideration

Fruiting was assumed to have begun when an ovary attained a diameter of 5 mm. and the number of days from germination to the start of fruiting is shown in Figure 1 for each sowing, plotted against the mean daylength (dawn to dusk) from germination to the start of fruiting. It can be seen that there is a hyperbolic relation between age at fruiting and daylength, and that the asymptotes are approximately 50 to 57 days and 10 to 10½ hours. Thus *under the experimental conditions prevailing* fruiting did not begin at mean daylengths below 10 to 10½ hours. As the mean daylength increased the age at fruiting decreased until fruiting began at a minimal age of 50 to 57 days, this being reached at a mean daylength of 13½ to 14 hours. Further increases in daylength were not associated with any further decrease in the age at fruiting.

The use of the term "daylength" in this context is not intended to imply a specific effect of light duration as distinct from total radiation or the light integral. Throughout this report the term has been used as a general description without any suggestion as to which of the component factors embraced by it are causally related to the phenomena discussed. This separation of the component factors is the next step in the development of the work, but is dependent on the availability of suitable controlled environment facilities.

If the relation with daylength described above is assumed to be causal it can be deduced that at daylengths greater than 13½ to 14 hours, or less than 10 to 10½ hours, the tomato is

insensitive to changes in daylength as far as age at fruiting is concerned, but that at daylengths between 10 to $10\frac{1}{2}$ hours and $13\frac{1}{2}$ to 14 hours it is extremely sensitive to changes in daylength, and over this small range of $3\frac{1}{2}$ hours the age at the start of fruiting changes from a very high value to a minimal value of 50 to 57 days.

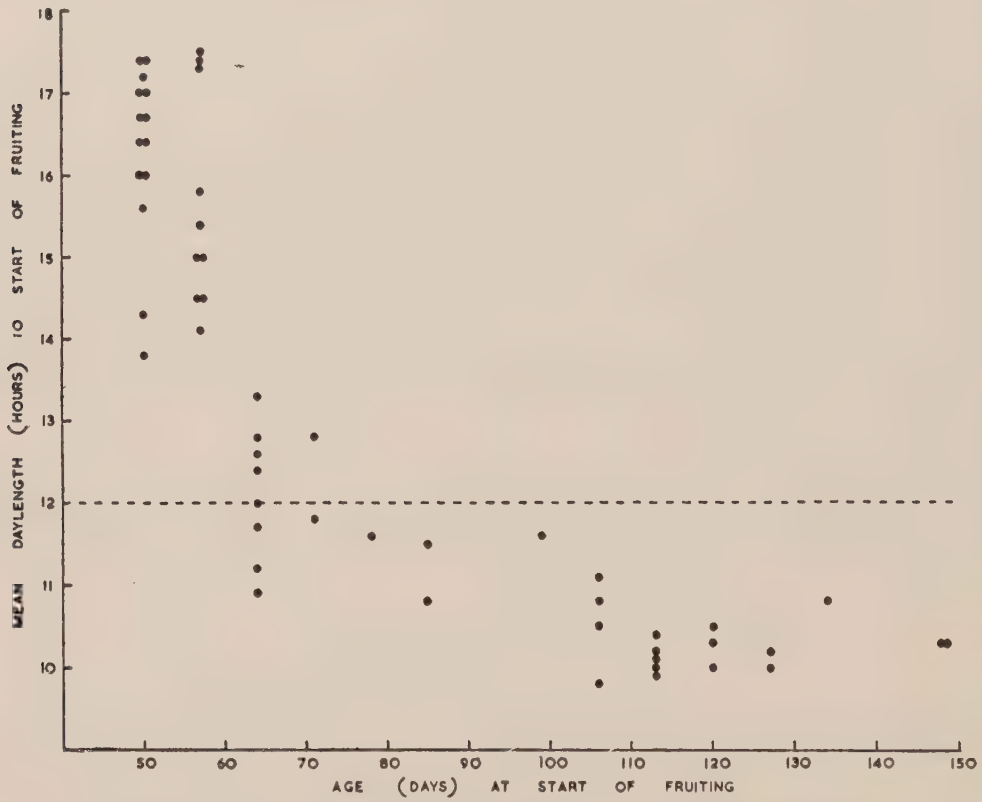


FIGURE 1. Relation between age at start of fruiting and previous light duration.

Once fruiting began all the sowings had a similar basic pattern of fruit production. Firstly there was a period of initial lag in which the weekly rate of fruit production increased very slowly. Then followed a period of rapid increase in the weekly rate of production until a maximal rate was attained. After this the rate of production progressively declined.

In order to study the initial lag period in fruit production it was necessary to define it quantitatively, and for the purposes of this study it was assumed to end when the weekly rate of fruit production per plant (as estimated from the sum of the cubes of the radii) exceeded 50 c.c. per week.

In Figure 2 the duration of the initial lag period in weeks is plotted against the mean daylength (dawn to dusk) of the initial lag period. It can be seen that the data fall into two groups, separated by the horizontal broken line, comprising sowings that experienced during their initial lag periods mean daylengths of either more or less than $11\frac{1}{2}$ hours. The sowings may thus be divided into two groups in relation to that condition of the environment in which the length of darkness was approximately equal to that of the light. If during the initial lag period the *daylength* was greater than the nightlength the duration of the period was unrelated to changes in daylength (the correlation coefficient being 0·03); it was relatively short and approximated to

a constant period of about five weeks. If during the initial lag period the *nightlength* was greater than the daylength the duration of the period was again unrelated to changes in daylength (the correlation coefficient being −0·002); it no longer, however, approximated to a constant period of about five weeks but ranged from this lower limit up to 33 weeks.

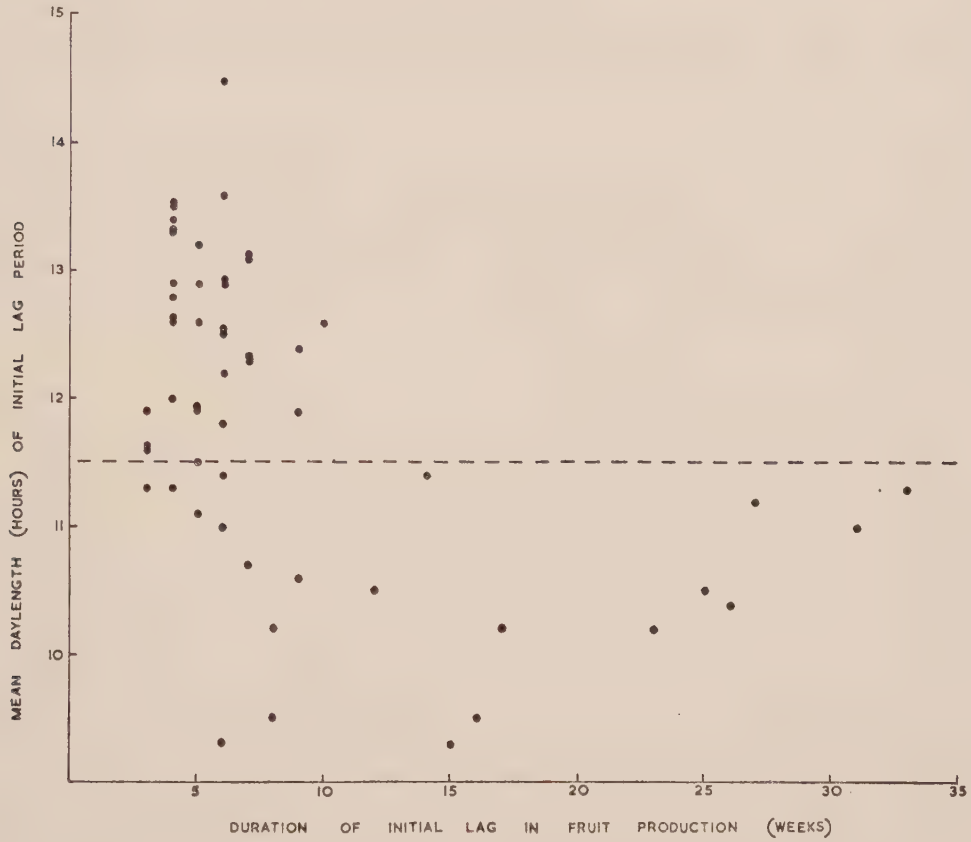


FIGURE 2. Relation between initial lag period and mean daylength during the period.

Thus if the relative length of the day and night be assumed to have a causal effect it can be deduced that if fruiting begins between the vernal and autumnal equinoxes (when the day is longer than the night) the initial lag in fruit production approximates to a constant. If fruiting begins between the autumnal and the vernal equinoxes (when the night is longer than the day) the initial lag period is variable. In the latter case the duration of the initial lag was found to be a function of the length of time at which fruiting began from the time of the year when light and darkness was equal (i.e., the vernal equinox), the lag period becoming shorter as the start of fruiting approached the vernal equinox. The regression coefficient for this relation is significant at the 0·05 level of probability, the regression equation being

$$x = 0{\cdot}96y + 4{\cdot}16$$

where x = duration of initial lag in weeks

y = number of weeks before mid-March at which fruiting began.

The durations of the periods of rapidly increasing fruit production are plotted in Figure 3 as horizontal lines extending over the times of the year at which they occurred. The sowings

segregate into two groups separated by the vertical broken line. Firstly, for the group of sowings that began rapid fruit swelling before about the middle of May, the rate of fruit production continued to increase each week as long as the daylength continued to increase, and all these sowings ended their period of increasing fruit production early in June or, in a few cases, earlier still. As soon as the daylength ceased to increase the weekly rate of fruit production began to decline. The duration of the period of rapidly increasing fruit production is thus a function of the length of time before the longest day from that point in time at which rapid fruit swelling begins; the correlation coefficient for this relation is 0·8 and is significant at the 0·001 level of probability.

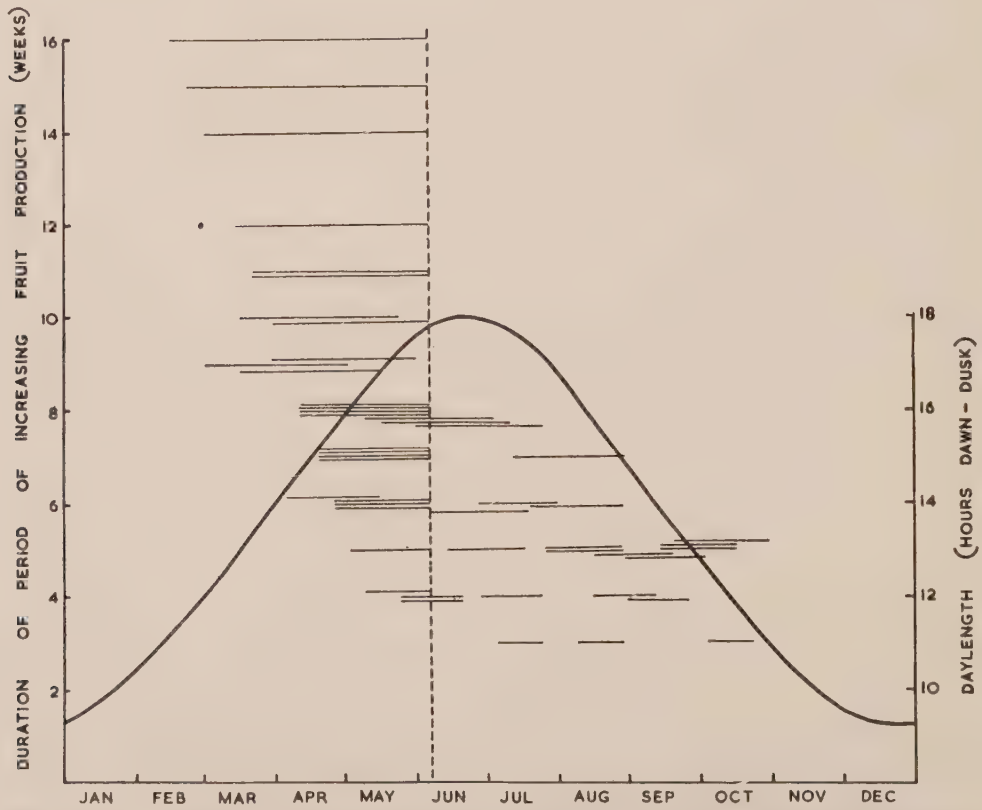


FIGURE 3. Relation between the duration of the period of rapidly increasing fruit production and the time of the year.

The second group of sowings comprises those that began rapid fruit swelling after mid-May In these the rate of fruit production increased despite the progressive decline in daylength to which the majority were subjected. The duration of the periods of increasing fruit production ranged from three to seven weeks and are not related to daylength, the correlation coefficient being 0·3 and not significant at the 0·05 level of probability.

The maximal rates of fruit production attained at the end of the period of rapid increase are plotted in Figure 4 against the times of the year at which they were attained. The crosses represent the sowings of the first group in Figure 3 (i.e., sowings that began rapid fruit swelling before mid-May), while the solid circles represent the second group (i.e., sowings that began rapid fruit swelling after mid-May). The magnitudes of the maxima of this second group were found to be related to the mean daylengths of the periods of rapidly increasing fruit production,

the greater the mean daylength the greater the maximal rate of fruit production attained. The correlation coefficient for this relation was 0·8, and it was significant at the 0·001 level of probability.

The possible causes of the variation in the maximal rates attained by the first group of sowings (i.e., those that began fruit swelling before mid-May) are not apparent. The relations of the maximum rate with the mean daylength of the period of increasing fruit production, the total hours of light received over this period, and the duration of the period were all non-significant at the 0·05 level of probability, the correlation coefficients being 0·3, 0·2 and 0·1 respectively.

Once the maximal rate of fruit production had been attained there followed a period of progressively declining production. It can be seen from Figure 4 that these periods of decline began at any time of the year after about the beginning of June. To determine whether the rates of fruit production subsequent to the attainment of the maximal rate were related to day-length the following method was employed. The mean weekly rate of fruit production was determined for each week from early June to the shortest day. These mean weekly values were

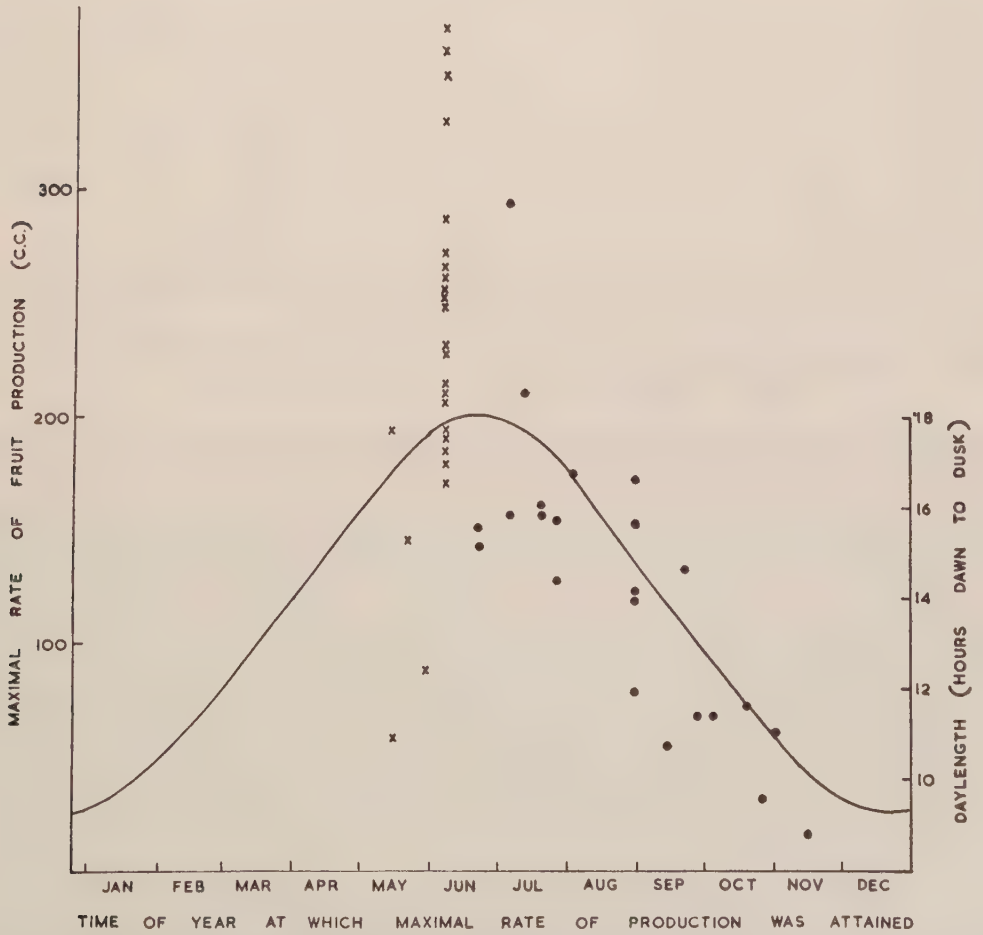


FIGURE 4. Relation between the maximal rate of fruit production and the time of the year at which it occurs.

plotted against the daylength at the beginning of the week as shown in Figure 5. It can be seen that there was a relation between daylength and the rate of fruit production once the tomato plant had attained its maximal rate of production. By extrapolation it can be inferred that fruit swelling should cease completely at a daylength of approximately 8 to $8\frac{1}{2}$ hours (dawn to dusk).

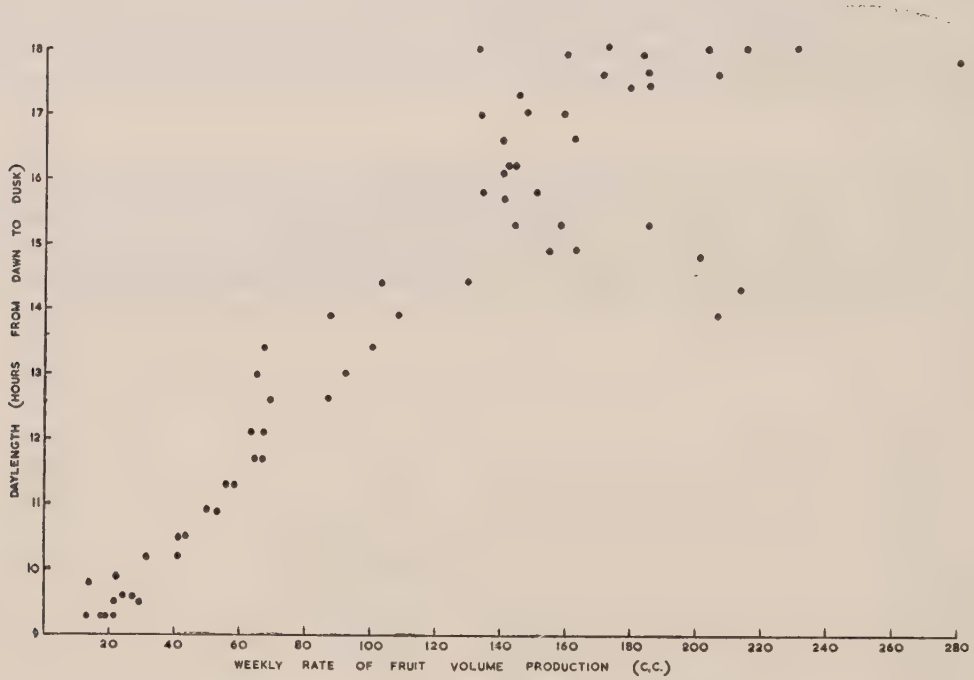


FIGURE 5. Relation between rate of fruit volume production and daylength during period of decreasing fruit volume production.

The period of decreasing fruit production described above ended when the daylength ceased to decline, i.e., at approximately the time of the shortest day. To determine whether the rate of fruit production after the end of the period of decline was related to daylength the following method was employed. The mean weekly rate of fruit production was determined for each week from the shortest day to early June for all sowings that were fruiting before early March. These mean weekly values were plotted against the daylength at the beginning of each week as shown in Figure 6. From Figure 5 it can be seen that the rate of fruit production declined to a very low level, approaching cessation, as the daylength declined to very short daylengths such as occur in mid-December. From Figure 6 it can be seen that when this virtually arrested condition of fruiting had been established the rate of fruit production ceased to be related to daylength and it remained at the extremely low level until the dusk-dawn equinox, when light and darkness are equal, was reached. When the duration of the light exceeded that of darkness the relation between fruit development and daylength occurred again, the weekly rate of fruit production increasing as the daylength increased.

The pattern of fruit production by the tomato is shown as a whole in Figure 7 (top). In this figure the weekly rates of fruit production of seven of the 56 weekly sowings have been plotted against the same time scale. It was not possible to plot data from more than seven sowings without the figure becoming too crowded, and the seven sowings were therefore chosen as being

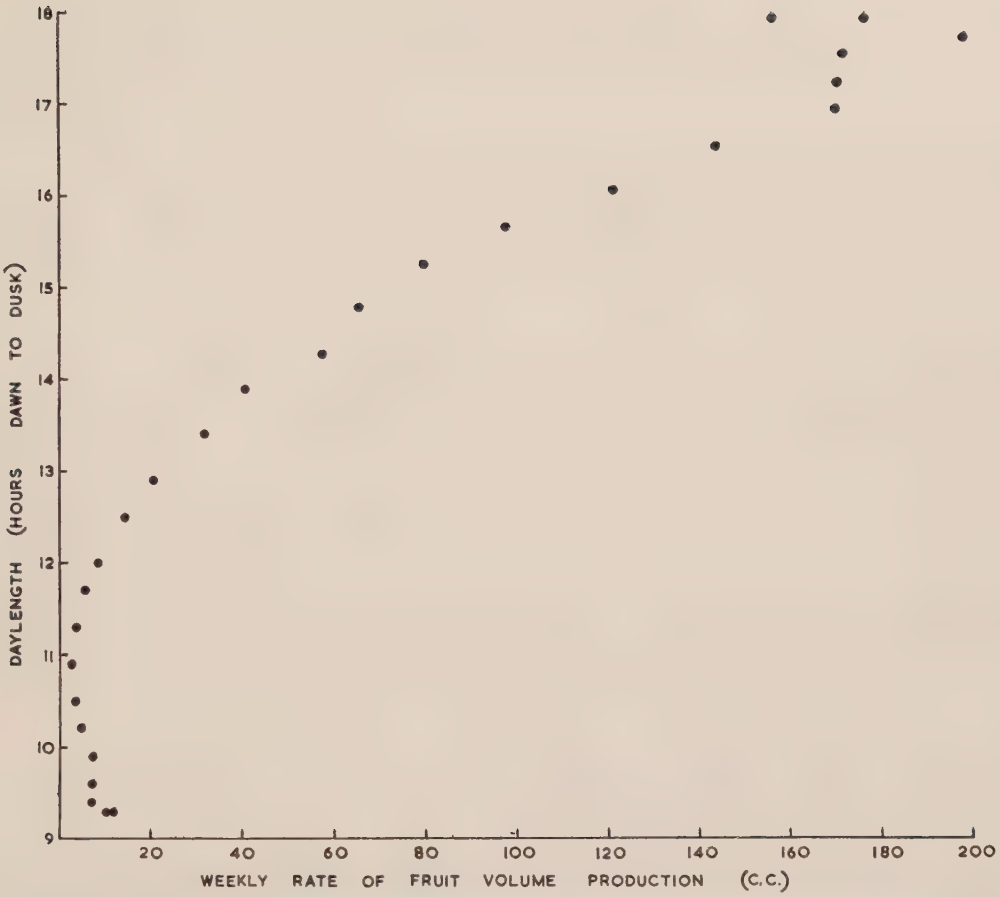


FIGURE 6. Relation between rate of fruit volume production and daylength during period of increasing fruit volume production.

representative of the seasonal patterns of development that occurred as the sowing date was advanced through the year. The sowings conformed to a common seasonal pattern which is shown diagrammatically in Figure 7 (bottom).

A plant was regarded as being mature when it had attained its initial maximal rate of fruit production. The seasonal pattern of development of such mature plants is shown as a continuous line. If plants began fruiting between the vernal and autumnal equinoxes (i.e., when the day was longer than the night) they exhibited a juvenile effect which is shown by the dotted lines; the weekly rate of fruit production increased each week, *even when the daylength was declining*, until the plants attained a maximal rate of fruit production, after which the subsequent seasonal pattern of their fruit development was identical with that of mature plants. As the daylength declined (i.e., as the date of the start of fruiting approached the autmnal equinox) this juvenile effect progressively changed until, when the duration of darkness exceeded that of the light, it was suppressed. Thus, when fruiting began after the autumnal equinox it remained at a very low level, approaching zero. If this condition, in which ovary swelling is almost at a standstill, is regarded as a manifestation of dormancy in the tomato it can be concluded that juvenile plants that begin fruiting after the autumnal equinox become dormant immediately. This

phenomenon is well known commercially among early tomato growers by the abortion of the first truss.

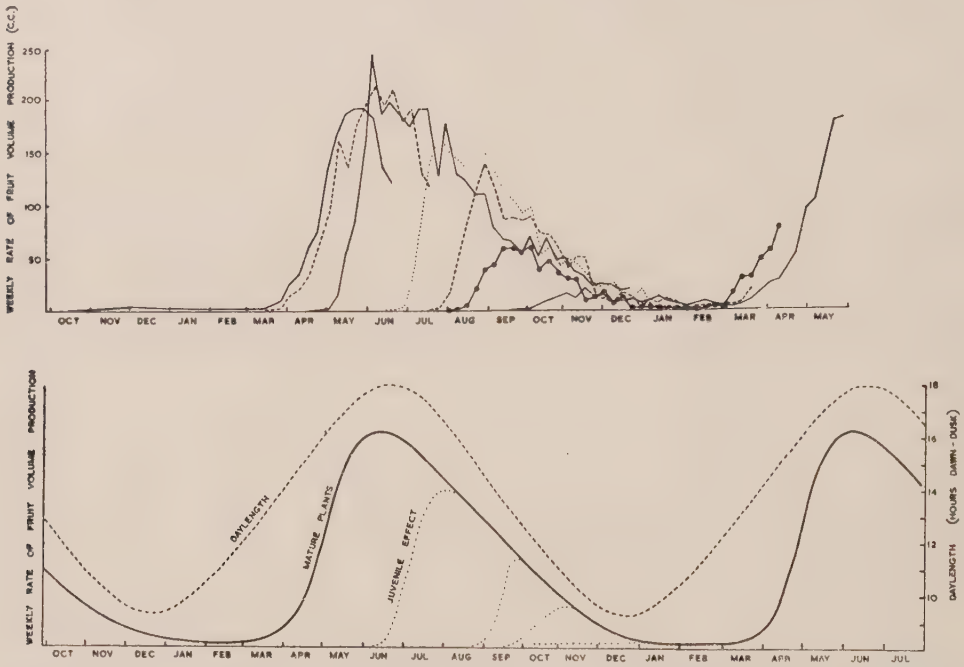

WEEKLY RATE OF FRUIT VOLUME PRODUCTION (c.c.)
250
200
150
100
50
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY
WEEKLY RATE OF FRUIT VOLUME PRODUCTION
DAYLENGTH
MATURE PLANTS
JUVENILE EFFECT
DAYLENGTH (HOURS DAWN - DUSK)
18
16
14
12
10
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL

FIGURE 7. The experimentally determined (upper) and diagrammatic (lower) seasonal pattern of fruit volume production.

If the seasonal pattern of fruiting in mature plants is considered as a whole (shown as a continuous line in Figure 7, bottom) the following picture emerges. From approximately the vernal equinox to the longest day the weekly rate of fruit production increases. During this time of the year the duration of the light exceeds that of the darkness and the daylength is progressively increasing; under these conditions the rate of fruit production is related to the daylength, and the relation is of the form shown in Figure 6 for daylengths greater than 12 hours. When the daylength ceases to increase, then the maximal rate of fruit production is attained and there follows a progessive decline in production as the daylength declines; again the rate of production is related to the daylength, but the relation is no longer as shown in Figure 6 but as shown in Figure 5. Thus Figure 5 illustrates the relation between the rate of fruit production and daylength of a "mature" plant (as defined earlier) during the time of the year when the daylength is decreasing, while Figure 6 illustrates the relation when the daylength is increasing. At the latitude at which the observations were made the daylength on the shortest day is just a little more than the daylength of 8 to 8½ hours (dawn to dusk) at which the relation with daylength shown in Figure 6 ceases and at which fruiting would cease if the relation were causal. Consequently, if the assumption of causality be correct, it can be deduced that from the longest day to the shortest day the weekly rate of fruit production of a mature plant declines until it approaches cessation by late December. Once this condition of dormancy is induced it is maintained *despite the increasing daylength* until the duration of the light exceeds that of darkness. When this occurs dormancy is broken and once again the relation with daylength of Figure 6 occurs.

SUMMARY

Seed of the 'Potentate' variety of tomato was sown at weekly intervals for 56 weeks, and weekly measurements of the diameters of every fruit were made to provide estimates of fruit volume production.

It was found that the pattern of development of the plants could be divided into (a) the period from germination to the start of fruiting, (b) an initial lag period in fruit volume production, (c) a period of rapidly increasing production, (d) a period of declining production, and (e) a period of arrested development when fruit swelling virtually ceased.

The duration of the period from germination to the start of fruiting was related to daylength.

The condition of arrested fruit development occurred from approximately the shortest day to the vernal equinox in mature plants which had already attained a maximal rate of fruit volume production. In juvenile plants arrested fruit development occurred (and was maintained) from approximately the autumnal equinox to the vernal equinox, i.e., during the period when the duration of darkness exceeded that of the light. In both juvenile and mature plants the condition of arrested fruit development ceased when the duration of the light exceeded that of darkness, and a period of increasing fruit volume production then ensued.

The rate of fruit volume production during this period of rapid increase was related to daylength and the relation was curvilinear. The rate of production continued to increase as long as the daylength continued to increase. When the daylength began to decline the rate of production began to decline, and the relation with daylength was then linear.

REFERENCES

1. Cooper, A. J. (1956). Further observations on the growth of the root and the shoots of the tomato plant. *Rep. 14th. Int. hort. Congr. 1955*, 589–95.

2. Cooper, A. J. (1958). Some 1956 growth analysis observations on the tomato. *Rep. Glasshouse Crops Res. Inst. 1956*, 30–3.

3. Cooper, A. J. (1958). Observations on growth trends of the tomato plant throughout the whole of the growing season. *J. hort. Sci.* **33,** 43–8.

4. Cooper, A. J. (1959). Interim report on the second stage of the tomato growth analysis. *Rep. Glasshouse Crops Res. Inst. 1958*, 59.

5. Cooper, A. J. (1959). Observations on the growth of the fruit on glasshouse tomato plants between March and September. *J. hort. Sci.* **34,** 96–103.

6. Cooper, A. J. (1959). Observations on the growth of the leaves of glasshouse tomato plants between March and August. *J. hort. Sci.* **34,** 104–10.

7. Cooper, A. J. (1961). Observations on the seasonal trends in the growth of the leaves and fruit of glasshouse tomatoes considered in relation to light duration and plant age. *J. hort. Sci.* **36,** 55–69.

8. Cooper, A. J. (1961). Observations on flowering in glasshouse tomatoes considered in relation to light duration and plant age. *J. hort. Sci.* **36,** 102–15.

Rep. Glasshouse Crops Res. Inst. 1961 (1962), pp. 118–121

5. THE EFFECT OF RATE OF SPAWNING ON THE CROPPING OF THE CULTIVATED MUSHROOM

by

D. COOKE and P. B. FLEGG

These experiments were done as part of a study of the variability of mushroom plot yields and, although limited in scope, are described because they may have practical value to growers. Apart from their original purpose the experiments can be regarded as a comparison of several rates of spawning using two ways of planting the compost with spawn.

Experimental methods

Three experiments were done, and in each the treatments and design were identical. Trays (6 sq.ft.) were spawned either with grain spawn spread evenly on the surface of the compost and worked in to a depth of about two inches, or with six to eight pieces of manure spawn planted two inches deep and evenly spaced. Four rates of spawning were used with each type of spawn, namely, one nominal pint of spawn per 6, 12, 24 and 48 square feet, and the eight treatments were replicated in six blocks.

The cropping of the experiments took place during the following periods: (i) May–June, 1960, (ii) August–October, 1960, (iii) January–March, 1961. The first two experiments were cropped for six weeks, the third for 12 weeks.

The spawn for these experiments came from one supplier; the cartons of grain contained about one pint of spawn and weighed about 450 g. (1 lb.), while the volume of the cylinders of manure spawn was about two pints and they weighed between 550 and 750 g. ($1\frac{1}{4}$ to $1\frac{3}{4}$ lb.) each. The use of either volume or weight as the basis of defining spawn rates has disadvantages because of differences in packing and moisture content. The nominal volume of the spawn was taken as the unit on which to base the four spawn rates, but the cartons were divided up by weight. Those cylinders of manure spawn which were particularly heavy were reduced in weight by 100 g. before being split.

As far as possible each treatment was cased when the mushroom mycelium had colonised at least three quarters of the compost. In general the heavier the rate of spawning the earlier the trays were cased.

The mushrooms were cut from the beds where the stalk leaves the casing layer and required trimming before being marketed. The yields given in the tables are of untrimmed weights; estimates of marketable weights were obtained by deducting 15% (Cooke and Flegg, 1962).

Results

In each experiment the appearance of the first pinheads, and the first picking of mushrooms (Table I), was earlier with increasing rates of spawning. This was most marked on the trays planted with pieces of manure spawn, where the average difference between the extreme treatments in date of first picking was nine days. There was a similar time difference between the extreme grain spawn treatments in Experiment 1, but in the later experiments the difference was only two days.

TABLE I

EFFECT OF SPAWNING RATE ON PERIOD (*IN DAYS*) FROM SPAWNING TO FIRST PICKING

Experiment	Grain spawn				Manure spawn				Mean	S.E. of difference
	Rate (*sq.ft. per pint*)				Rate (*sq.ft. per pint*)					
	6	12	24	48	6	12	24	48		
1	50·3	53·2	53·0	59·7	56·0	57·0	60·9	64·2	56·8	± 1·65
2	34·5	35·5	36·7	36·0	37·2	41·2	42·8	55·8	40·0	± 3·50
3	38·9	39·5	40·3	41·3	39·3	41·9	43·5	45·0	41·2	± 0·62

The weight, number and average weight of the mushrooms harvested in the six-week period from the date on which the first mushrooms were picked in each experiment are given in Tables II, III, and IV. This method of assessing comparative yields penalises those treatments which are late in starting to crop and is thus more appropriate when considering the commercial aspects of the results. However, even when the yields were totalled to allow six weeks' cropping from each tray the results were similar, and they are therefore not given. The similarity of the results when either method of assessment is used is because those treatments which were late in starting to crop also yielded poorly and produced very little in the fifth and sixth weeks.

TABLE II

EFFECT OF SPAWNING RATE ON WEIGHT OF MUSHROOMS (*IN LB. PER SQ.FT.*) PICKED IN SIX WEEKS' CROPPING FROM DATE OF FIRST PICKING IN EACH EXPERIMENT

Experiment	Grain spawn				Manure spawn				Mean	S.E. of difference
	Rate (*sq.ft. per pint*)				Rate (*sq.ft. per pint*)					
	6	12	24	48	6	12	24	48		
1	0·71	0·50	0·36	0·25	0·36	0·25	0·16	0·07	0·33	± 0·043
2	1·49	1·16	0·94	0·74	0·58	0·23	0·32	0·14	0·70	± 0·183
3	2·25	1·84	1·77	1·78	1·62	1·63	1·72	1·39	1·75	± 0·084
Mean	1·49	1·17	1·03	0·92	0·85	0·70	0·73	0·53	0·93	± 0·069*

* refers to comparisons between rates of a given type of spawn but not to comparisons between different types of spawn

The level of yield in the three experiments differed greatly, and they might be regarded as having given successively poor, moderate and good yielding crops; in the first two experiments the compost was heavily infected with *Chaetomium* sp. Even so, the weights of crop obtained from the treatments showed similar trends in each experiment.

TABLE III

EFFECT OF SPAWNING RATE ON NUMBERS OF MUSHROOMS (*PER SQ.FT.*) PICKED IN SIX WEEKS' CROPPING FROM DATE OF FIRST PICKING IN EACH EXPERIMENT

Experiment	Grain spawn				Manure spawn				Mean	S.E. of difference
	Rate (*sq.ft. per pint*)				Rate (*sq.ft. per pint*)					
	6	12	24	48	6	12	24	48		
1	27·7	16·0	13·8	11·3	12·1	7·3	5·5	2·4	12·0	± 1·88
2	24·4	15·0	13·9	9·6	9·2	3·1	4·5	1·7	10·2	± 3·49
3	57·9	50·3	47·5	66·8	38·5	52·1	56·1	38·9	51·0	± 3·88

TABLE IV

EFFECT OF SPAWNING RATE ON AVERAGE WEIGHT (*OZ.*) OF MUSHROOMS

Experiment	Grain spawn				Manure spawn				Mean	S.E. of difference
	Rate (*sq.ft. per pint*)				Rate (*sq.ft. per pint*)					
	6	12	24	48	6	12	24	48		
1	0·420	0·511	0·426	0·367	0·501	0·554	0·490	0·446	0·464	± 0·050
2	1·05	1·40	1·10	1·23	1·28	1·25	1·32	1·30	1·24	± 0·242
3	0·627	0·598	0·608	0·427	0·677	0·507	0·506	0·589	0·567	± 0·042

At equal rates of spawning, surface planting of grain spawn gave much heavier yields than planting with pieces of manure spawn. In particular, the highest rate of manure spawn (1 pint per 6 sq.ft.) gave approximately the same yield as the lowest rate of grain spawn (1 pint per 48 sq.ft.). Grain spawn did particularly well relative to manure spawn in the second experiment. Increased rates of spawning led to heavier yields with both types of spawn, though the increase was greater with grain than with manure spawn.

The yields after 12 weeks' picking in Experiment 3 showed similar trends to those for six weeks. The trays receiving the highest rates of spawning gave 3·0 and 2·6 lb. per sq.ft. for grain and manure spawn respectively, and those receiving the lowest rates 2·3 and 2·4 lb. per sq.ft. respectively.

The effect of the treatments on the number and average weight of mushrooms differed in the first two experiments from that in the last. In Experiments 1 and 2 the effect on number was almost identical to that on weight. The treatments had no significant effect on average weight per mushroom in the two experiments except that in Experiment 1 the mushrooms from the manure spawn treatments were slightly heavier than those from the grain spawn treatments. Although there were significant differences between numbers and average weights of mushrooms in the third experiment, the results showed no simple pattern.

Discussion

A comparison at equivalent rates of spawning, in terms of bulk, showed surface planted grain spawn to be superior to manure spawn planted as pieces. As the main bulk and weight of spawn is that of the medium a comparison on this basis is not always satisfactory. The performance of the spawns may also be compared on the basis of the cost of spawn planted per unit area. The price of grain and manure spawn was, respectively, six and three shillings per pint. Thus, grain spawn at 1 pint per 24 sq.ft. may be considered equivalent to manure spawn at 1 pint per 12 sq.ft., each costing 3d. per sq.ft. On this basis grain spawn planted on the surface was superior to manure spawn planted as pieces, the average difference from the three possible comparisons being 0·28 lb. (marketable weight 0·24 lb.) per sq.ft. Further experiments are required to compare the spawns when they are both planted in the same way.

Over the range of rates of spawning used, from 1 to 8 pints per 48 sq.ft., the mean increase in yield obtained for every extra pint of grain spawn was 3·9 lb. (marketable weight 3·3 lb.) of mushrooms. The value of the increase in yield at 3/- per lb. would be 9/11d., which is substantially larger than the additional cost of 1 pint of grain spawn, namely 6/–. Similar calculations on the results obtained with the manure spawn show an increased yield of 2·2 lb. (marketable weight 1·9 lb.) of mushrooms, value 5/8d., for each extra pint of manure spawn costing 3/–. Thus increased rates of spawning with either system of spawning resulted in increased yields which more than covered the extra cost of the spawn. To what extent this

applies at rates in excess of 1 pint per 6 sq.ft. is not known and requires further investigation.

Although the compost used in the first two experiments was infected with *Chaetomium* sp., increasing the rate of spawning in these two experiments from 1 to 8 pints of spawn per 48 sq.ft. gave on the average at least an extra half pound per sq.ft. when grain spawn was used. Thus a high rate of spawning may be regarded as a safeguard should the quality of the compost be poor and likely to support the development of *Chaetomium* sp.

Acknowledgments

We thank Miss I. Warman, Mrs. B. Howard, Miss A. Blake and Mr. J. White for their help throughout this series of experiments.

SUMMARY

Four rates of spawning, ranging from 1 pint to 8 pints per 48 sq.ft., were compared in three experiments. Both grain spawn planted on the surface and manure spawn planted in small pieces were used in each experiment.

Although the level of yield varied considerably between the three experiments, increased rates of spawning led in all experiments to an earlier start of cropping and increased yields. With grain spawn the mean rate of increase was 3·9 lb. of untrimmed mushrooms (marketable weight 3·3 lb.) per pint, and with manure spawn 2·2 lb. (marketable weight 1·9 lb.) per pint. The two types of spawn were compared on the basis of equivalent cost, a given rate of grain spawn being considered equivalent to the rate of manure spawn which used twice the bulk of spawn on the same area; on this basis grain spawn was superior to manure spawn, the average difference in yield being 0·28 lb. (marketable weight 0·24 lb.) per sq.ft. The mean yield of grain spawn at the lowest rate was 0·92 lb. (marketable weight 0·78 lb.) per sq.ft. Numbers and average weights of mushrooms did not show consistent trends over the three experiments.

At current market prices the increase in return obtained by increasing the spawn rate more than met the additional cost of the spawn. It is suggested that a high rate of spawning may ensure a reasonable yield from a compost which is not entirely satisfactory.

REFERENCE

Cooke, D. & Flegg, P. B. (1962). The relation between yield of the cultivated mushroom and stage of maturity at picking. *J. hort. Sci.*, **37,** (in the press).

APPENDIX

PUBLICATIONS 1961

(Booth, C.) and Ebben, M. H. *Thielavia reticulata* sp. nov. *Trans. Brit. mycol. Soc.*, **44,** 214–6.

Broadbent, L. The epidemiology of tomato mosaic: a review of the literature. *Rep. Glasshouse Crops Res. Inst. 1960*, 96–116.

Broadbent, L. Tobacco mosaic can be kept out. *Grower*, **56,** 619–21.

Broadbent, L. Brassica virus diseases. *Gdnrs' Chron.*, **149,** 102.

Broadbent, L. Control of potato viruses by insecticides. *Agriculture, Lond.*, **68,** 404–7.

Broadbent, L. (and Heathcote, G. D.). Winged aphids trapped in potato fields, 1942–1959. *Ent. exp. & appl.*, **4,** 226–37.

Broadbent, L. (and Heathcote, G. D.). Local spread of potato leaf roll and Y viruses. *Eur. Potato J.*, **4,** 138–43.

Broadbent, L., (Heathcote, G. D., Brown, P. H. and Wheeler, G. F. C.). Home-production of seed for early potatoes. 1. Prevention of virus infection by spraying for aphid control. *Exper. Hort.*, **4,** 8–12.

Broadbent, L., (Brown, P. H. and Wright, R. C. M.). Home-production of seed for early potatoes. 2. Comparison of home-produced and imported seed. *Exper. Hort.*, **5,** 37–9.

Bunt, A. C. Some physical properties of pot-plant composts and their effect on plant growth. I. Bulky physical conditioners. *Plant and Soil*, **13,** 322–32.

Bunt, A. C. Some physical properties of pot-plant composts and their effect on plant growth. II. Air capacity of substrates. *Plant and Soil*, **15,** 13–24.

Bunt, A. C. Some physical properties of pot-plant composts and their effect on plant growth. III. Compaction. *Plant and Soil*, **15,** 228–42.

Bunt, A. C. Loamless composts can give good results. *Grower*, **56,** 20, 864.

Cooke, D. and Flegg, P. B. Harvesting practices. *MGA Bull.*, **134,** 55–61.

Cooper, A. J. Observations on the seasonal trends in the growth of the leaves and fruit of glasshouse tomato plants, considered in relation to light duration and plant age. *J. hort. Sci.*, **36,** 55–69.

Cooper, A. J. Observations on flowering in glasshouse tomato plants considered in relation to light duration and plant age. *J. hort. Sci.*, **36,** 102–15.

Cooper, A. J. Controlling the growth of the glasshouse tomato. Part I. *Tomato & Cucumber Marketing Board Journal*, **10,** 232–41.

Cooper, A. J. Controlling the growth of the glasshouse tomato. Part II. *Tomato & Cucumber Marketing Board Journal*, **10,** 265–8.

Cooper, A. J. Controlling the growth of the Glasshouse tomato. Part III. *Tomato & Cucumber Marketing Journal*, **10,** 297–301.

Cooper, A. J. Blotch research. *Grower Annual, 1962*, 126–7.

Darby, L. A. The production of improved tomato varieties. *N.A.A.S. Quart. Rev.*, **53,** 1–10.

Flegg, P. B. Electrical conductivity of the casing layer in relation to fruiting of the cultivated mushroom. *Rep. Glasshouse Crops Res. Inst. 1960*, 117–24.

Flegg, P. B. Mushroom composts and composting: areview of the literature. *Rep. Glasshouse Crops Res. Inst. 1960*, 125–34.

Flegg, P. B. The natural accumulation of soluble salts in the casing layer of mushroom beds. *J. hort. Sci.*, **36,** 139–44.

Flegg, P. B. The effects of adding soluble salts to the casing layer on the yield and size of cultivated mushrooms. *J. hort. Sci.*, **36,** 145–8.

Flegg, P. B. Experiments with the casing layer used for mushrooms. *Exp. Hort.*, **5,** 44–9.

Flegg, P. B. (and Loughton, A.). Cereal straws used for mushroom composts. *Exp. Hort.*, **5,** 50–2.

HACK, H. R. B. A method of automatic solar radiation integration with printed records including an assessment of its reliability. *Arch. Met., Wien*, **11** (1), 60–9.

HACK, H. R. B. Soil moisture tensiometers: some limitations and applications to growth studies. *Advances in horticultural science and their applications. Proc. 15th Int. hort. Congr., 1958*, **1**, 400–17.

HESLING, J. J. Problems in the routine hot-water treatment of chrysanthemum stools. *Plant Path.*, **10**, 139–41.

HOLLINGS, M. Virus diseases of chrysanthemums. *Nurserym. & Seedsm.*, **132**, 464–5.

HOLLINGS, M. Virus in carnations. *Nurserym. & Seedsm.*, **132**, 568–9.

HOLLINGS, M. Viruses attacking cucumbers. *Nurserym. & Seedsm.*, **132**, 646–7.

HOLLINGS, M. Virus and the lettuce. *Nurserym. & Seedsm.*, **132**, 765.

HOLLINGS, M. Virus and its effects on some ornamental shrubs. *Nurserym. & Seedsm.*, **132**, 390–1.

HOLLINGS, M. Virus in some herbaceous ornamentals. *Nurserym. & Seedsm.*, **132**, 1026–7.

HOLLINGS, M. and STONE, OLWEN M. Carnation etched ring: a preliminary report on an undescribed disease. *Rep. Glasshouse Crops Res. Inst., 1960*, 94–5.

HOWLES, R. Inactivation of tomato mosaic virus in tomato seeds. *Plant Path.*, **10**, 160–1.

HUGHES, J. T. Colorimetric determination of "Kelthane" residues. *Analyst*, **86**, 756–7.

HUSSEY, N. W. Recent work on the control of the Worthing Phorid. *MGA Bull.*, **144**, 195–205.

HUSSEY, N. W. and WYATT, I. J. Some economic considerations in the control of mushroom pests. *MGA Bull.*, **136**, 145–55.

PARR, W. J. and HUSSEY, N. W. The specific status of some European strains of the Glasshouse Red Spider Mite. *Rep. Glasshouse Crops Res. Inst., 1960*, 91–3.

READ, W. H. Current usage and recent developments in the use of fungicides in glasshouse crops. *Fungicides in Agriculture and Horticulture*, 14–22. Society of Chemical Industry, London.

SHEARD, G. F. Irradiation of lettuce during propagation. *Exp. Hort.*, **4**, 71–2.

SHEARD, G. F. Progress at the Glasshouse Crops Research Institute. *Hort. Trade J.*, **65**, (26), 19–21.

SMITH, J. W. M. How to save seed from new varieties. *Grower*, **55**, 1077.

SMITH, R. J. and READ, W. H. Investigations on fungitoxic derivatives of salicylaldehyde. I. The 3–, 5– and 3,5– chlorinated derivatives of salicylanilide and salicyl-para-chloroanilide. *Ann. appl. Biol.*, **49**, 102–9.

SMITH, R. J. and READ, W. H. Investigations on fungitoxic derivatives of salicylaldehyde. II. Chlorinated and brominated derivatives of salicylideneaniline and related compounds as eradicants of cucumber powdery mildew (*Erysiphe cichoracearum* D.C.). *Ann. appl. Biol.*, **49**, 233–41.

SMITH, R. J. and READ, W. H. Investigations on fungitoxic derivatives of salicylaldehyde. III. Some N-substituted derivatives of halogenated salicylideneimines as eradicants of cucumber powdery mildew. *Ann. appl. Biol.*, **49**, 242–5.

WINSOR, G. W., DAVIES, J. N. and LONG, M. I. E. Liquid feeding of glasshouse tomatoes: the effects of potassium concentration on fruit quality and yield. *J. hort. Sci.*, **36**, 254–67.

WYATT, I. J. The male of *Henria psalliotae* Wyatt (Diptera: Cecidomyiidae). *Proc. R. ent. Soc. Lond.* (*B*), **30**, 1–3.

In addition, contributions to advisory bulletins published by the Ministry of Agriculture, Fisheries and Food (London: H.M.S.O.) were made as follows:—

SHEARD, G. F. Bulletin No. 151, "Carnations under Glass".

SHEARD, G. F. Bulletin No. 92, "Chrysanthemums".

APPENDIX

METEOROLOGICAL RECORDS, 1961

(Agricultural-Meteorological Station: Glasshouse Crops Research Institute, Worthing Road, Rustington, Littlehampton, Sussex)

	Air temperature (*mean screen, °F.*)		Rainfall (*inches*)	Sunshine * (*mean daily hours*)	Soil temperature (*mean at 0900 hr. G.M.T., °F.*)				Wind ‡ (*mean daily miles run*)
	Max.	Min.			4 in.	8 in.	2 ft.	4 ft.	
January	45·3	34·8	4·31	1·83	38·4	39·6	42·2	43·9	180
February	49·8	38·8	2·48	2·14	43·1	43·8	44·9	45·1	166
March	53·6	36·3	0·08	5·25	43·1*a*	44·5	46·7	46·4	110
April	56·5	44·3	2·89	3·22	47·7*b*	50·7	51·2	49·1	117
May	60·5	43·6	1·44	7·88	54·6	54·9	55·7	53·0	110
June	66·2	48·2	1·04	8·26	60·2	60·0	59·1	55·9	120
July	68·2	51·5 *c*	1·40	6·61	63·0	62·5	62·4	59·2	139
August	68·6	53·2	1·00	6·01	61·4	61·2	61·8	59·5	172
September	67·7	53·4	2·19	4·81	59·9	60·2	61·8	59·8	131
October	60·4	47·7	4·68	4·19	51·5	53·3	56·9	57·2	209
November	50·4	40·0	3·42	2·16	43·2	45·0	49·2	51·4	165
December	45·3	33·8	4·65	2·53	38·0	39·5	44·1	46·9	156
Total or mean	57·7	43·8	29·58	4·57	50·3	51·3	53·0	52·3	148

* recorded by Campbell-Stokes instrument

‡ recorded at height of 6 ft. 6in. above ground level

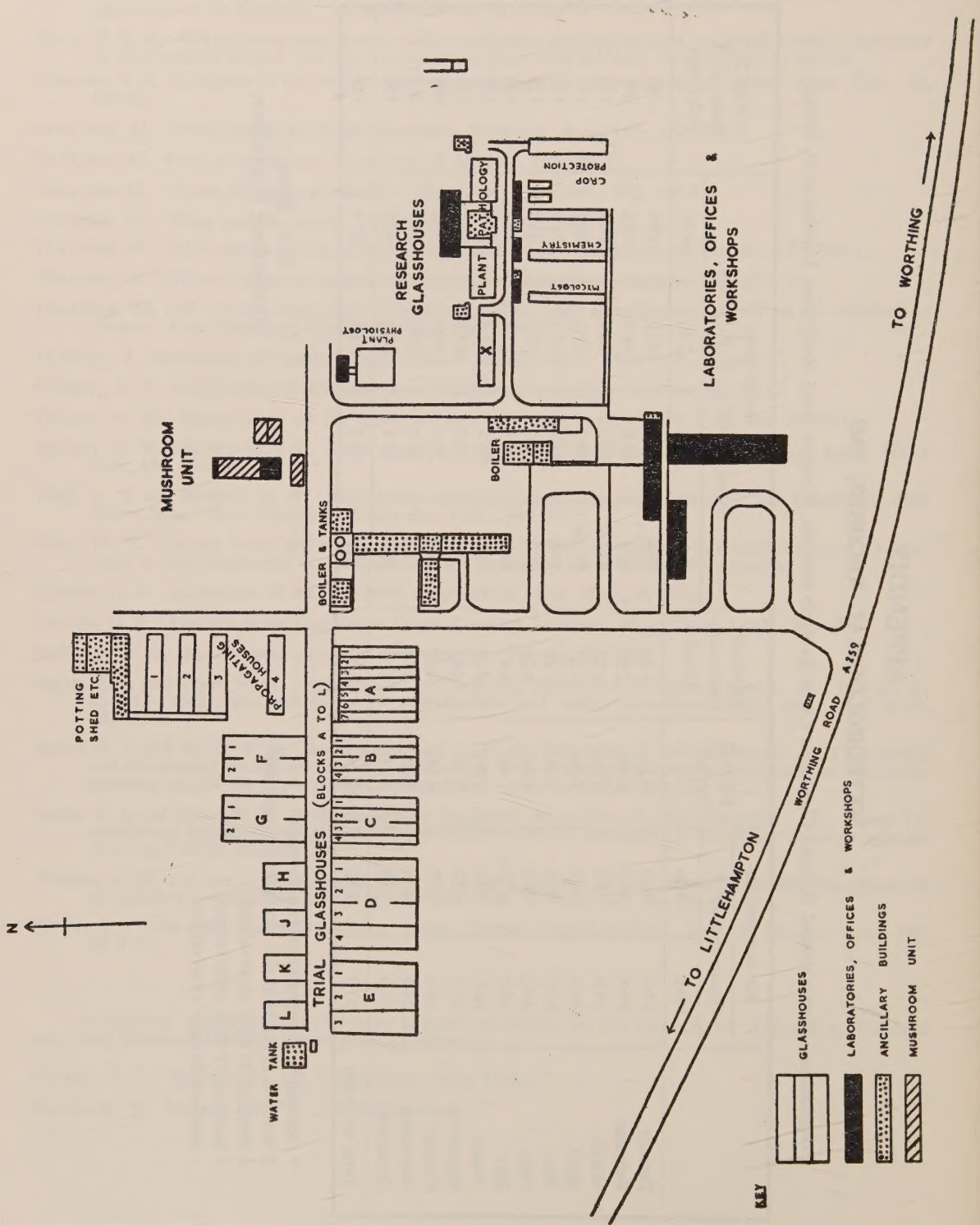
a based on 25 days' observations

b based on 17 days' observations

c based on 30 days' observations

A. C. BUNT
Horticulture Department

GLASSHOUSE CROPS RESEARCH INSTITUTE



Layout of the glasshouses, laboratories, and other buildings

THE JOURNAL OF HORTICULTURAL SCIENCE

THE JOURNAL OF HORTICULTURAL SCIENCE exists to publish results of research on fruit and other perennial crops, vegetables and flowers. The Publication Committee welcomes papers from both temperate and tropical countries describing original investigations of interest to those engaged in scientific research and the practice of horticulture. Papers for publication and all communications should be sent to the Editors, East Malling Research Station, Maidstone, Kent.

Papers in the current Volume 37 (1962) come from the Research Stations at Long Ashton and East Malling, the Glasshouse Crops Research Institute, the National Vegetable Research Station, the Bee Research Department at Rothamsted, Reading University and Wye College, the N.A.A.S., and from California, New South Wales and New Zealand. Of particular interest to growers of glasshouse crops are studies on the culture of tomato, especially the nutrition of that crop, a mainly technical study of mushroom experiments and a report on yield in relation to stage of maturity, and a nutritional study of carnations under glass.

The Volume also includes reports on experiments with apples, pears, plums and black currants; vines; spring cabbage and pears; and tulips.

Among the subjects discussed are the causes and control of variability, frost damage and the effect of winter temperatures on flowering, nutrition, pollination, storage, propagation, viruses, the inheritance of woolly aphid resistance, apple codlin moth and silver leaf in plums.

The Journal is issued in quarterly parts and is published by Headley Bros. Ltd., 109 Kingsway, London, W.C.2, to whom intending subscribers should apply. The subscription rates for the current volume are 60 shillings per volume (rate for Canada and the U.S.A. $8.50) or 20 shillings for a single number. Back numbers of several volumes are available from the publishers.